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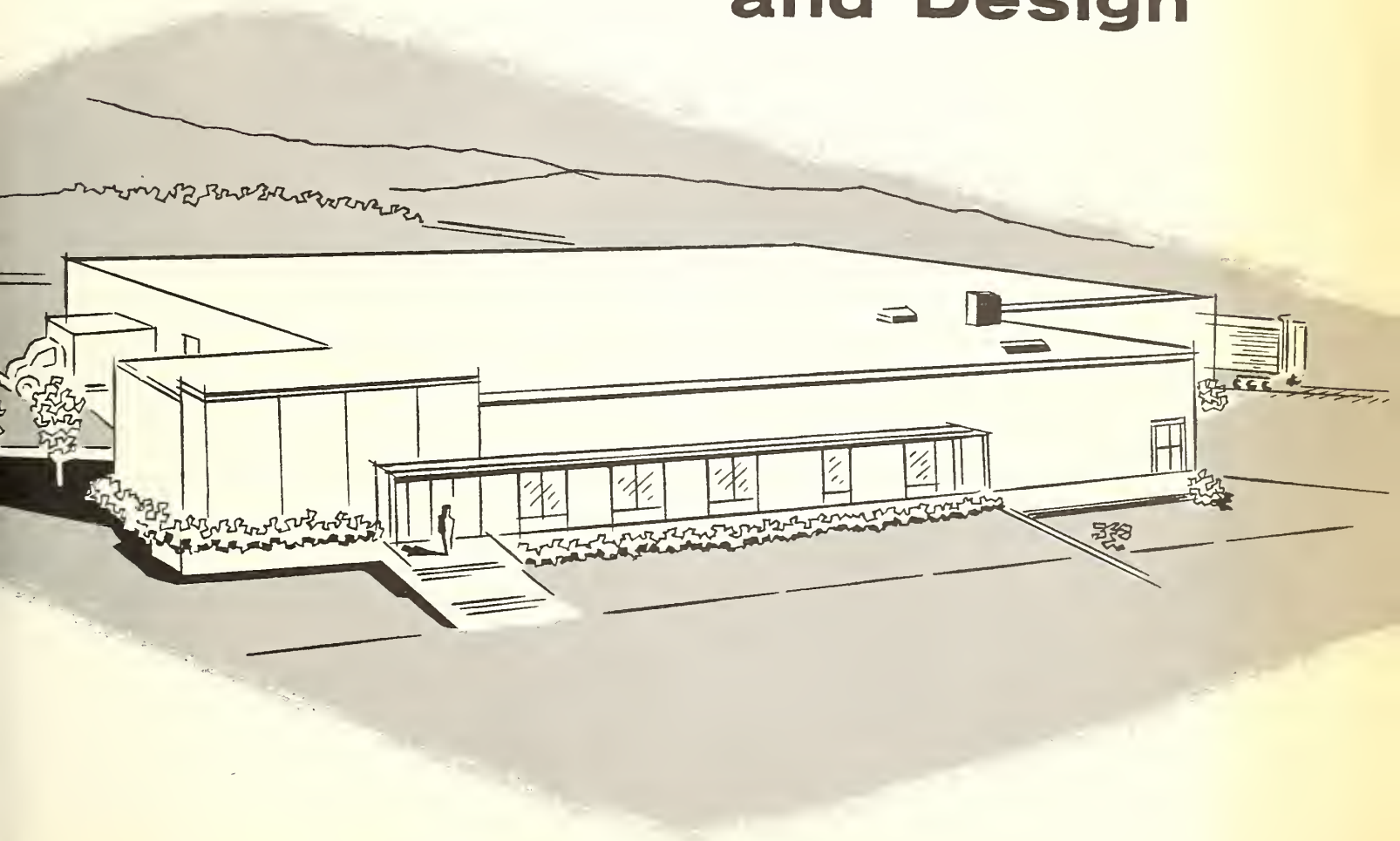
7 Marketing Research Report No. 467

WHOLESALE FRUIT AND VEGETABLE WAREHOUSES

• Guides for Layout and Design



UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Transportation and Facilities Research Division
Washington, D. C.

PREFACE

This report is one of a group to be issued on the results of research work on the physical handling of packages of perishable produce at various stages in the marketing system. The project under which this research is conducted is supervised by Joseph F. Herrick, Jr., marketing research analyst, Handling and Facilities Research Branch, Transportation and Facilities Research Division, Agricultural Marketing Service.

The layouts and designs that provide the basis for this report were prepared by The McPherson Co., architects and engineers, Greenville, S.C., under a research contract with the U.S. Department of Agriculture.

Many persons and organizations in the fresh fruit and vegetable distribution industry gave advice and assistance. Among the organizations were: L.F. Fadler Co., Springfield, Mo., and Pittsburg, Kans.; A. Reich & Sons, Inc., Kansas City, Mo.; United Fresh Fruit & Vegetable Association, Washington, D.C.

Frederick C. Winter, professor of industrial engineering, Columbia University, formerly consultant to the Transportation and Facilities Research Division, gave guidance and suggestions on many technical problems.

Other related reports on the handling of perishable food products issued by the U.S. Department of Agriculture include:

Methods, Equipment and Facilities for Receiving, Ripening, and Packing Bananas. Marketing Research Report 92, June 1955.

Some Improved Methods of Handling Frozen Food in Wholesale Plants. Marketing Research Report 107, November 1955.

The Effect of Apple Handling Methods on Storage Space Utilization. Marketing Research Report 130, July 1956.

Materials Handling in Public Refrigerated Warehouses. Marketing Research Report 145, June 1957.

Comparative Costs of Handling Apples at Packing and Storage Plants. Marketing Research Report 215, March 1958.

Apple Sorting Methods and Equipment. Marketing Research Report 230, July 1958.

Loading Out Fruits and Vegetables in Wholesale Warehouses. Market Research Report 282, March 1959.

Mechanically Processing Wholesale Frozen Food Orders, AMS–317, June 1959.

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SUMMARY

The modern service-wholesale warehouse for fresh fruits and vegetables should provide space for efficient, low-cost handling and for maintaining quality of the products stored. Plans for a warehouse should be based on the following layout principles:

1. Maximum utilization of space.
2. Direct flow of commodities.
3. Flexibility in use of space.
4. Protection of quality of products.
5. Future expansion.
6. Maximum utilization of equipment.
7. Safety and comfort of employees.
8. Minimum supervision.

Site selection and an efficient layout plan are closely related. A poorly situated and proportioned lot will prevent the development of an efficient warehouse. A building site should provide enough land area for construction of a well-designed warehouse and also permit expansion at some time in the future.

The service wholesaler who plans to build or remodel a warehouse should start his planning with the selection of the materials handling equipment he will use. At the same time he must analyze his business for tonnage handled and for seasonality. The average inventory stored must also be established to properly determine space requirements. Full consideration should also be given to the problem of quality maintenance. Insulation and refrigeration capacity should be adequate to provide high humidity and low temperature in the warehouse.

To show how sound layout planning can lead to an efficient warehouse design, a representative service-wholesale business was selected for analysis. Annual volume was assumed to be 1,000 carload equivalents with planned future expansion to 2,000 carloads. The wholesaler would handle a general line of fruits and vegetables, and package produce in consumer units. Provision was made to add a tomato-ripening-and-packing operation if desired.

A 48- by 40-inch pallet system with a forklift truck and pallet transporters was selected to receive and store the commodities. A portable belt conveyor with a retractable cantilevered extension would be used to move the assembled commodities into delivery trucks.

The general storage area was to be held at 50° F. year round. Temperatures in wet and dry cold storage rooms would be held at 32° F., with the humidity level for the former 90 to 95 percent and for the latter, 85 to 90 percent.

Three sets of two layouts each were prepared. Each set included a layout for the initial volume and one for the expanded volume. One layout set was based on a requirement that the initial volume be accommodated in a warehouse that was square. The second set required a layout in which the outside dimensions were not restricted initially. The third set simulated a multistore building in which the depth was not to exceed 100 feet in the initial or expanded layout.

Since the unrestricted layout was considered to be the most flexible and efficient, it was selected for further study. Detailed design drawings were prepared, including a site plan, floor plan, sections, elevations, and so on. The design was prepared for climatic conditions of the Cincinnati, Ohio, area and then modified for the climates represented by New Orleans, La., and Minneapolis-St. Paul, Minn.

Issued August 1961

WHOLESALE FRUIT AND VEGETABLE WAREHOUSES

Guides for Layout and Design

By Robert K. Bogardus, *industrial engineer*, Transportation and Facilities Research Division, Agricultural Marketing Service

BACKGROUND

Planning, designing, and building a modern warehouse presents a major problem for fruit and vegetable wholesalers. Decisions made prior to construction can have a lasting effect on costs and on efficiency of operations. Recognizing that not only wholesalers but also architects and engineers need basic information on the requirements for handling, storing, and warehousing fresh fruits and vegetables, the Agricultural Marketing Service undertook an engineering research program dealing with these problems. The purpose of this report is to present guides and standards for the layout and design of warehouses for fruits and vegetables.

The type of business for which warehouses were planned is known as service wholesaling. A "service wholesaler," as the term is used in this report, is a wholesale distributor who obtains orders for fruits and vegetables through salesmen or by telephone and who makes deliveries to his customers. Many service wholesalers have learned that their old, outmoded facilities would not accommodate the modern handling methods and equipment they wished to adopt. As a result, many of them are planning either to construct new facilities or to remodel existing buildings.

Three separate climatic areas in the United States were selected for study in an effort to meet the needs of service wholesalers on a national basis. The cities selected as typical for these areas were Cincinnati, Ohio, New Orleans, La., and Minneapolis-St. Paul, Minn. These areas were selected to determine the warehouse materials and designs required for varied climatic conditions. The thickness of insulation, the capacity of refrigeration equipment, and other building features and designs were checked.

The layouts were developed for a service wholesale business with an annual volume of 1,000 carlot equivalents. This volume was considered to be average for the industry. Provision was made for expansion to 2,000 carlots annually.

The layouts and designs presented in this report would have to be modified to suit the specific needs of individual service wholesalers. However, wholesalers and architects will find that many of the features illustrated can be incorporated in most warehouses. In this way efficient warehouses can be constructed for both present and future needs.

OBJECTIVES OF WAREHOUSE PLANNING

Planning before a warehouse is built is a sound investment of time and money. Errors avoided in warehouse layout and design as well as in site selection can result in savings in the initial cost of construction as well as in annual operating costs.

LAYOUT PRINCIPLES

A number of general principles should be considered when planning warehouse layouts. These principles are based on the experience of industrial engineers who have studied warehouse designs over a period of years.

Maximum Utilization of Space

Every component of warehouse space, both horizontal and vertical, should be planned. Each square foot should have an assigned use so that it is economically justified. If high ceilings are provided, then ducts, pipes, refrigeration units, and other overhead obstructions should be placed so that they do not interfere with use of the vertical space. A minimum vertical clearance should be maintained throughout the warehouse storage areas. Knowing why each cubic foot is needed and how it is going to be used will permit the design of an economical facility of adequate size.

Direct Flow of Commodities

Storage areas, aisles, doors, and equipment should be so located and used that commodities received by truck or rail will traverse the shortest distances possible into storage areas. Aisles should be located so that commodities can be moved into, within, and out of warehouse storage areas in the least amount of time. Minimum transportation distances and reduced time in movement result in fewer man-hours for handling fruits and vegetables and lower labor costs.

Flexibility in Use of Space

Seasonal changes in the availability of fruits and vegetables, future improvements in operating methods, new types of materials-handling equipment, and possible changes in the operations performed make it highly desirable to provide space that can be used for more than one purpose. The warehouse should have large, open areas with a minimum of column obstructions, as well as doors strategically located for both present and future use.

Protection of Quality of Products

The most successful service wholesalers recognize the need for maintaining quality and avoiding physical damage to the products they handle. They accomplish this by providing planned space for stored products so that refrigerated air can circulate throughout all storage areas and to individual containers. Proper spacing between loads and adequate aisle space permit movement of produce into and out of storage areas without physical damage.

Future Expansion

In planning the initial facility, the wholesaler should provide for future expansion. An estimate of future growth of his business will be needed. A warehouse designed for expansion will minimize costs of storage space added later.

Movable walls or partitions can be provided in the direction of growth. Cold-storage rooms and permanently installed equipment can be so located that they do not present a costly barrier to increasing the size of the warehouse.

Initial construction should allow for some growth in business volume. However, to provide all the space that might be needed to accommodate possible business growth in a 10- to 20-year period in the future may easily result in a financial burden that could not be sustained by interim business volumes. A definite plan for expansion, with building features designed to accommodate it, will permit warehouse growth at low cost.

Maximum Utilization of Equipment

Adequate aisles, proper platform widths and heights, and arrangement of storage and work areas for direct flow of produce into, within, and out of the warehouse will expedite the movement of properly maintained handling equipment. As a result, equipment utilization will be high. The number of units of handling equipment and the investment required for them can then be kept to a minimum.

Safety and Comfort of Employees

Adequate lighting, properly planned passageways for foot traffic, and unobstructed storage spaces would help to avoid accidents involving warehouse workers. Comfort facilities, conveniently located, help to minimize time away from work and permit maintenance of acceptable sanitary levels.

Minimum Supervision

Designated storage areas that are easily accessible reduce the time that foremen have to spend in selecting storage areas and directing rewarehousing required to consolidate space. Less time would be required for inventory control. A "first-in first-out" inventory policy is easier to achieve in a well-planned warehouse layout.

SITE SELECTION

Preliminary layout sketches should be available before any commitment is made in the selection of a building site. A well-designed, efficient warehouse cannot be built on a narrow or irregularly shaped lot. The added annual operating cost on such a site would be high enough to justify care in seeking out a suitable lot.

The lot selected must be near railroads and major highways. If the preliminary warehouse plans are adaptable to access on more than one side, the builder will not be restricted to one particular site. Most well-designed layouts can be reversed to provide some of the flexibility that may be necessary.

The plans considered initially should indicate the extent and direction of future expansion, and enough land should be bought to allow for the expected growth. Failure to buy enough land initially can lead to costly acquisitions in the future. Additional purchases may even be precluded because of adjacent commercial or industrial construction. The choice then is to relocate or to operate inefficiently. Either choice is costly.

The lot selected must have enough space for entrance and exit of the service wholesaler's delivery trucks as well as the large highway semitrailers that bring in fresh supplies of fruits and vegetables. Semitrailers require wide road aprons so they can be maneuvered into position at the warehouse platform for unloading.

Soil and subsoil at the site should not be overlooked. Poor load-bearing soils and inefficient drainage can cause surprising increases in costs of foundation and site preparation. Lots with heavy slopes should be avoided since the roads, rail sidings, and building site proper must be nearly level. Grading and the possible need for retaining walls would add to construction costs.

Individual wholesalers will have to determine the need for their lots to be close to customers being serviced. It is doubtful that the advantage of closeness to customers would overcome the disadvantages (higher property costs, traffic congestion, and poor selection of sites) which are usually found in downtown areas.

SPECIAL REQUIREMENTS

There are many variables to consider when dealing with fresh fruits and vegetables. Physical handling and storage areas are affected by the proportionate volume of each commodity. The shape, dimensions, strength, and gross weight of the various packages determine how high they may be stacked and how carefully they must be handled. Some commodities are available only during certain months and others are available year round (*15*).[1]

The proportionate volumes of various commodities handled by an individual service wholesaler may follow somewhat the distribution pattern based on national averages (table 1).

TABLE 1.—*Composition by commodity of 1,000 carload equivalents of fruits and vegetables handled yearly by a representative service wholesaler* [1]

Commodity	Annual carload equivalents	Weight per package	Packages per carload [2]	Estimated weight per carload	Total weight
	Carloads	*Pounds*	*Packages*	*Tons*	*Tons*
Potatoes	250	100	400	20. 0	5, 000. 0
Bananas	156	90	250	[3] 11. 2	1, 747. 2
Lettuce	110	42	640	13. 4	1, 474. 0
Cabbage	45	50	500	12. 5	562. 5
Apples	42	50	800	20. 0	840. 0
Celery	41	60	420	12. 6	516. 6
Oranges	35	40	1, 000	20. 0	700. 0
Grapefruit	29	40	1, 000	20. 0	580. 0
Watermelons	29	33	800	13. 2	382. 8
Onions	27	50	600	15. 0	405. 0
Carrots	26	50	700	17. 5	455. 0
Tomatoes	26	32	675	10. 8	280. 8
Cantaloups	19	85	310	13. 2	250. 8
Sweetpotatoes	15	55	500	13. 8	207. 0
Corn	15	50	500	12. 5	187. 5
Grapes	13	32	1, 100	17. 6	228. 8
Peaches	11	55	400	11. 0	121. 0
Lemons	11	40	1, 000	20. 0	220. 0
Other [4]	100	[5] 46	[5] 618	13. 6	1, 360. 0
Total or average	1, 000			[5] 15. 5	15, 519. 0

[1] Distribution based on national averages drawn from studies by the U.S. Department of Agriculture and surveys made by the service wholesale division of the United Fresh Fruit & Vegetable Association.

[2] Based on table of factors for use by Fruit and Vegetable Market News offices to convert truck shipments and receipts to approximate carlot equivalents (revised 1954).

[3] Based on a carload of green bananas. Packed bananas without stems would equal 9.0 tons per carload equivalent.

[4] See table 7 in the appendix for data on individual commodities.

[5] Weighted average.

On the other hand, local demands for individual commodities may vary or the service wholesaler may specialize in certain commodities. As a result, volumes of some items will exceed the national ratios. For that reason individual business statistics should be collected for volumes of each commodity actually handled. These figures will provide a more accurate basis for space planning by each wholesaler than national averages.

[1] Italic numbers in parentheses refer to items in "Literature Cited," p. 31.

In developing warehouse layouts for a wholesale fruit and vegetable business with an annual volume of 1,000 carlot equivalents, it was necessary to assume certain specific business characteristics. The characteristics were selected to represent active service wholesale businesses in all parts of the United States.

The representative service wholesaler received 450 carloads of fruits and vegetables in railroad cars and 550 in trucks. Eighty percent of this volume was handled in an 8-month period, that is, at a rate of 10 percent per month, and 20 percent in the remaining 4-month period at a rate of 5 percent per month.

During the 8-month period, average weekly receipts would equal 23 carloads, with 10 coming by rail and 13 by truck. In the 4-month period, weekly receipts would amount to 5 carloads by rail and 7 by truck.

The business would operate 6 days a week with a maximum daily volume equal to 25 percent of the weekly volume. It was assumed that on any one day during the week the maximum amount shipped would approximate six carload equivalents. This quantity would be loaded on 16 delivery trucks having an average load capacity of 6 tons. Ripened bananas would be cut and packed at a maximum rate of one carload equivalent per day.

It was also assumed that inventory would turn over 80 times per year, or once every 4½ calendar days.

MATERIALS-HANDLING EQUIPMENT

The first step after establishing the general nature and size of the business was to select the type of materials-handling equipment to be used. A forklift truck (fig. 1) and pallet system was chosen because of its adaptability to a variety of package sizes, its ability to use vertical storage space, and the low labor cost associated with its use. Powered pallet transporters (fig. 2) would supplement the forklift truck.

A 48- by 40-inch,[2] two-way, double-face, flush-stringer, nonreversible wood pallet (fig. 3) was selected. This size has

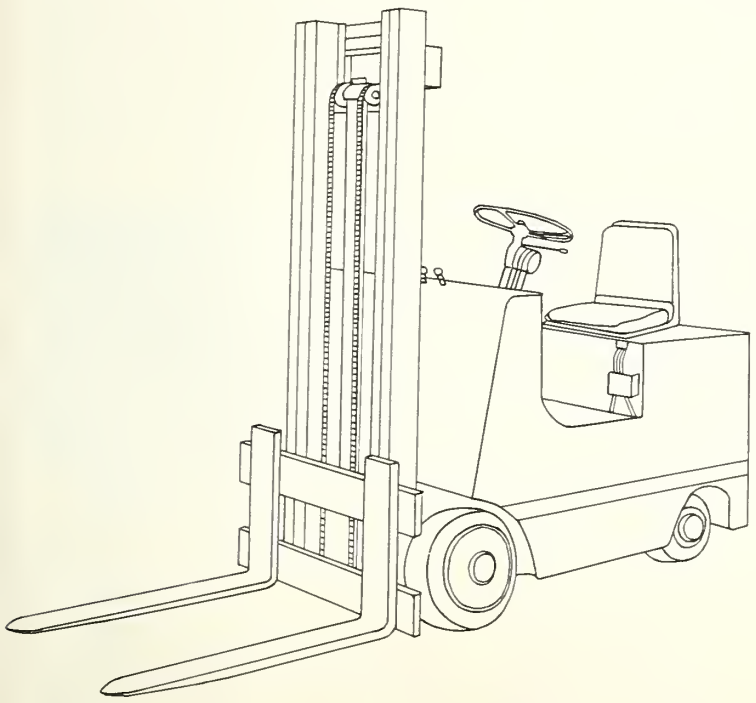

FIGURE 1.—*Forklift truck.*

[2] Standard pallet dimensioning requires that the stringer length be designated before the width (*11*).

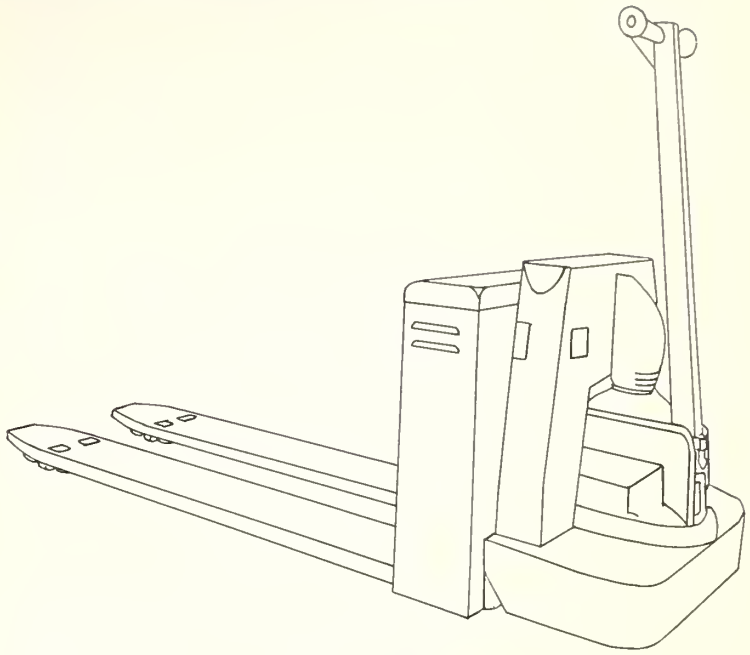

FIGURE 2.—*Pallet transporter.*

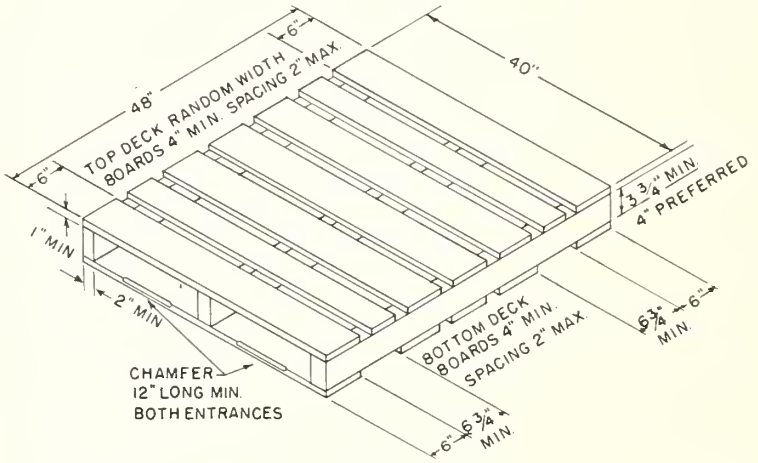

FIGURE 3.—*Wood pallet, 48 by 40 inches.*

advantages for both present and future handling operations. A wide variety of package sizes and shapes can be built into efficient loads on a platform base of this size.

Pallets of these dimensions are available in all sections of the United States. They are widely used in the manufacturing and service industries. Their size permits them to be used in loading both railroad cars and trucks. The 48-inch side fits across the width of a railroad car and the 40-inch side across the width of a truck. Pallet loading of fruits and vegetables on both railroad cars and highway trucks at shipping points may be commonplace in the future. A warehouse designed around this pallet size can quickly benefit from the reduced labor requirements when palletized shipments are available. A four-way pallet, which can be picked up by the forklift truck from any one of four sides, would be necessary for use in both the railroad car and the delivery truck.

For the layouts that follow it was assumed that a portable belt conveyor with a retractable cantilevered extension would be used to move all commodities into delivery trucks. Four-wheel hand platform trucks (fig. 4), having superstructures for hanging eight stems of bananas, would be used for receiving that fruit. Stems of green bananas would be hung manually from ceiling hooks in the ripening rooms. Stems of

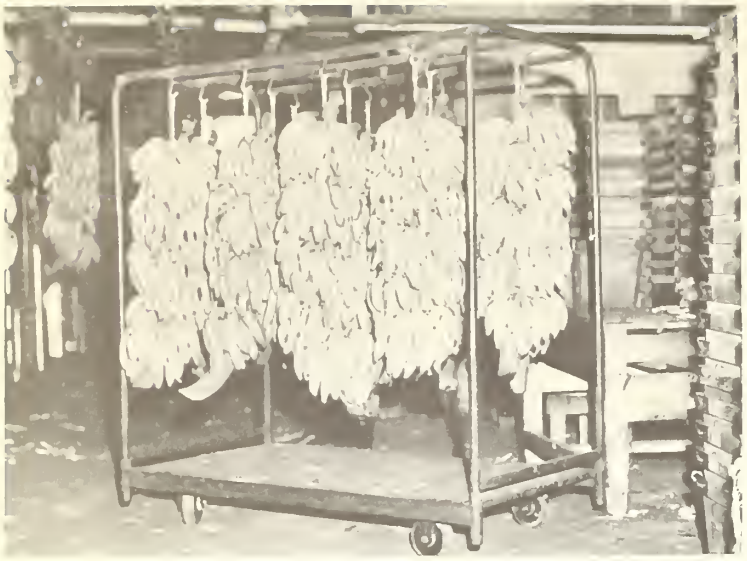

FIGURE 4.—*A four-wheel banana truck.*

ripe bananas would be transported to the cutting and packing areas (fig. 5) on the handtrucks. Boxes of cut, packed bananas would be palletized and moved to a holding area or to the order-assembly area for shipment.

REFRIGERATION

In planning a warehouse for the movement of 1,000 carload equivalents annually, it was decided to provide a refrigeration system that would maintain a year-round temperature of 50° F. in the general storage areas. Humidity there would vary with the weather. Thirty-two degrees Fahrenheit would be maintained in the dry and wet cold storage rooms. Humidity would be high in these rooms because of the low temperature maintained. (See the appendix for temperatures and humidities recommended to maintain quality of fruits and vegetables.)

The commodities stored would be distributed as follows:

General storage (50° F.)	Dry cold storage (32° F.)	Wet cold storage (32° F.)
Beans, green	*Apples	Artichokes
*Cantaloups	Cranberries	Asparagus
Cucumbers	*Grapefruit	Beans, lima
Egg plant	*Grapes	Beets
*Lemons	*Lettuce	Broccoli
Melons, other	*Oranges	Brussels sprouts
Okra	*Peaches	*Cabbage
*Onions	Pears	*Carrots
Peppers, sweet	Squash, summer	Cauliflower
*Potatoes, sweet		*Celery
*Potatoes, white		*Corn
Pumpkins		Endive
Squash, winter		Escarole
*Tomatoes		Peas, green
*Watermelons		Radishes
		Rhubarb
		Spinach
		Turnips

*These commodities account for approximately 90 percent of the total annual volume handled.

Day-to-day fluctuations in volumes stored may necessitate some shift in the items located in the wet and dry cold storage rooms. If so, part of the lettuce could be stored in the wet cold storage room, or carrots and radishes in polyethylene bags could be stored in the dry cold storage room.

Maintaining the general storage area at 50° F. is an important adjunct to providing top-quality fruits and vegetables to the consumer. Wholesalers whose warehouses are already designed to maintain that temperature report three advantages: (1) Quality maintenance is better in controlled-temperature storage than in unconditioned areas; (2) losses due to spoilage in the warehouse are sharply reduced; and (3) shelf life of products is extended thus reducing spoilage in retail stores.

Vacuum cooling at the shipping point and packaging in fiberboard cartons has made it possible and practical to shift lettuce from the wet to the dry cold storage area. Vacuum cooling and packing in fiberboard cartons eliminates the need for top icing.

Temperatures must be varied within a certain range in the rooms used to ripen bananas and in those for ripening tomatoes. The recommended temperature range for bananas is 56° to 68° F. Water sprays maintain the needed high humidities in the ripening rooms Technical details on the factors that control the ripening process and details of ripening room layout have been published (*2, 6*).

Ripening requirements for green tomatoes require temperatures of 55° to 70° F. with humidities at 85 to 90 percent. Ripened tomatoes should be held at 50° to maintain their quality until they are shipped (*9, 12*).

PROVIDING FOR EXPANSION

The warehouse layouts for this representative service wholesaler were designed for easy expansion to accommodate a 100-percent increase in business volume. Growth from 1,000 to 2,000 carload equivalents annually was anticipated.

Another aspect of expansion was to make provision for the addition of ripening rooms for green tomatoes. If the service wholesaler elected to perform this operation, then the necessary rooms could be incorporated in the original plan or built later at a reasonable cost. At the 1,000-carload volume, space would be provided for ripening green tomatoes at an annual rate of 25 carload equivalents; at 2,000 carloads, space to ripen 50 carloads a year would be needed.

FLOOR AREA

Space requirements depend upon the volumes to be handled within the warehouse. Volumes stored are affected by seasonality and inventory turnover. Infrequent peak volumes, that occur just before certain holidays or possibly during the seed potato season, should not be the basis for calculating storage areas. For the representative service wholesaler, a monthly rate equal to 10 percent of his annual volume (100 carload equivalents per month) and an inventory turnover

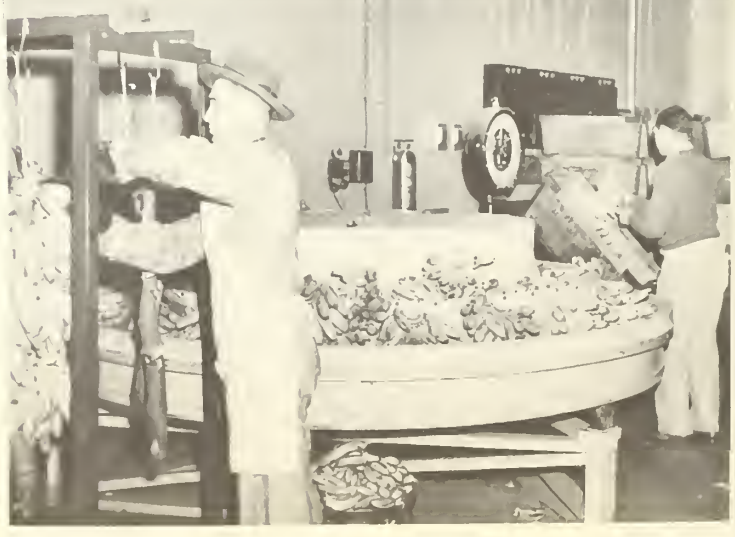

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FIGURE 5.—*Cutting and packing area.*

period of 4½ days were used to calculate space needed for commodity storage.

An important consideration in determining the floor area required is the extent to which vertical storage space can be utilized. Forklift trucks can be used to reduce the total floor space needed: they can lift a loaded pallet and place it on top of another, allowing two pallets to be stored on the floor area required for one.

Some forklift trucks can stack loaded pallets four high. However, the height of a stack is limited by the ability of the bottom containers to sustain the weight of one or more pallets. In recent years new containers for produce have not been strong enough to allow many pallets to be stacked on top of each other without serious damage to the stored produce. Without special supports, such as pallet racks to prevent this type of damage, only one out of every four pallet loads on the average can support the weight of another loaded pallet. This restricted use of vertical storage space was widely accepted at the time this research was initiated. As a result, storage areas were designed with a clear ceiling height of 12 feet to accommodate a maximum of two loaded pallets per stack. Additional height in the storage areas could not be utilized.

Researchers are currently investigating pallet racks and other stacking devices. If the cost of acquiring, installing, and using these devices can be justified in terms of better use of vertical storage space as well as in reduced floor area requirements, new layouts and designs incorporating the devices will be developed.

Details of the floor area calculations are in the appendix.

Aisles.—Each aisle has a specific function and each function will determine its width. For example, when the aisle is to provide for one-way traffic, the minimum width should be equal to the maximum width of the load carried by the materials handling equipment plus 24 inches. For 48- by 40-inch pallets, the minimum aisle width would be 67 inches, including an allowance of 3 inches for possible package overhang. If two-way traffic is to be accommodated, then the load width should be doubled and 36 inches added to give a minimum aisle width of 122 inches.

Another factor controlled the basic aisle width that was used in the layouts that follow. Since the main function of a warehouse is to provide storage space, the purpose of aisles is to provide access to storage areas. Counterbalanced forklift trucks, on the average, require an aisle width of 120 inches to make a right-angle turn. To expedite pallet movement into and out of storage areas, 12 more inches should be allowed for clearance. The additional space will help to eliminate damage to stored commodities and to the handling equipment. The clearance plus the width needed for a right-angle turn would give a minimum aisle width of 11 feet.

Whenever a determination of aisle width is made, the type of equipment to be purchased should be known. Then a specific figure for aisle width can be based on the dimensions provided by the manufacturer. An 11-foot aisle will be adequate for most equipment.

Aisle widths may exceed these minimum figures when unusual warehouse traffic conditions occur. Variations from the minimum are discussed in the section on "Warehouse Layouts."

WAREHOUSE COMPONENTS

Most service wholesale warehouses are composed of a large central working area in which space for general storage, order assembly, supply storage, prepackaging, and split-package areas would be provided. Dry and wet cold storage rooms, banana ripening, cutting, and packing rooms, and in some warehouses tomato ripening rooms are provided. Office, maintenance, boiler, and refrigeration equipment areas are included within the structure.

General storage.—For the representative service wholesale business of 1,000 carload equivalents annually, at least 4,000 square feet of space, excluding aisles, would be required for commodity storage. Aisles servicing general storage were set at a minimum of 11 feet so that movement in and out of storage could be accomplished efficiently and easily.

Order assembly area.—The order assembly area provides temporary storage of one or more pallet loads of each commodity handled by the service wholesaler. A portable motorized belt conveyor with a telescoping extension for truckloading is in the center of the order assembly area (fig. 6). A working aisle, 3 feet wide, is provided on each side of the conveyor.

Pallets can be stored 2 deep, for a total of 80 pallets with 40 on each side of the area. A service aisle 11 feet wide at the perimeter of the order assembly area permits quick movement of fresh supplies into the area as truckloading proceeds. Pallets, conveyor work aisles, and conveyor require approximately 1,900 square feet of floor space.

Supply storage.—Space must be provided for slow-moving supplies such as pallet loads of flat cartons for bananas; paper, plastic, and fiberboard containers for prepackaging fruits and vegetables; and display materials for retail customers. No published or recorded data or criteria were available for estimating floor area requirements for these materials. Observation of a number of service wholesale warehouses indicated that at least 1,000 square feet should be made available for this purpose.

Prepackaging and split packing.—Almost all service wholesalers provide their customers with less than full packages of certain commodities. Making up the smaller packages requires a work area of at least 200 square feet. Space requirements for prepackaging vary in relation to the commodities and volumes packed. Service wholesalers looking to the future felt strongly that an area of at least 2,000 square feet should be provided for all packaging except for bananas. This area would be used for sorting and packing lines for ripened tomatoes as well as for equipment needed to prepackage other fruits and vegetables.

Dry and wet cold storage.—Two cold storage rooms of equal floor area and equal clear ceiling height were selected for commodities to be stored at 32° F. Construction of both rooms would be identical so that either could be used for dry or wet storage. A bumper guard to keep pallets 8 inches from the insulated walls, an 11-foot aisle, and space for pallet stacks resulted in a need for at least 1,700 square feet per room.

Banana rooms.—Recommended layouts for banana ripening, cutting, and packing rooms were published in an earlier report (*2*). For the present report, four 1-carload banana ripening rooms of approximately 300 square feet each were selected. Some wholesalers prefer rooms with ½-carload capacity, but the additional construction, instrumentation, and controls would increase the cost of space divided in this manner.

Tomato ripening room.—Space for a tomato ripening room was considered to be optional in developing a layout plan. Provision was made for later construction of such a room. Space calculations were based on facilities for ripening a carload of tomatoes a week. Two rows of eight pallets, each separated by an 11-foot aisle, would require approximately 600 square feet of space. Adequate ceiling height would be provided to stack pallets two high when required.

Offices.—A service wholesaler handling 1,000 carloads of fruits and vegetables annually will need a number of different types of space in the office section of the warehouse. A general office for combined shipping and billing would include telephones or switchboard facilities. A small lobby to accommodate salesmen, an office for the wholesaler, and a warehouse and foreman's office would also be necessary. A general-purpose room for sales conferences, merchandising training programs, and personnel meetings was included in the office plans. Space for salesmen would be available in the general office or the conference room. Toilet facilities for warehouse and office personnel would be included in the

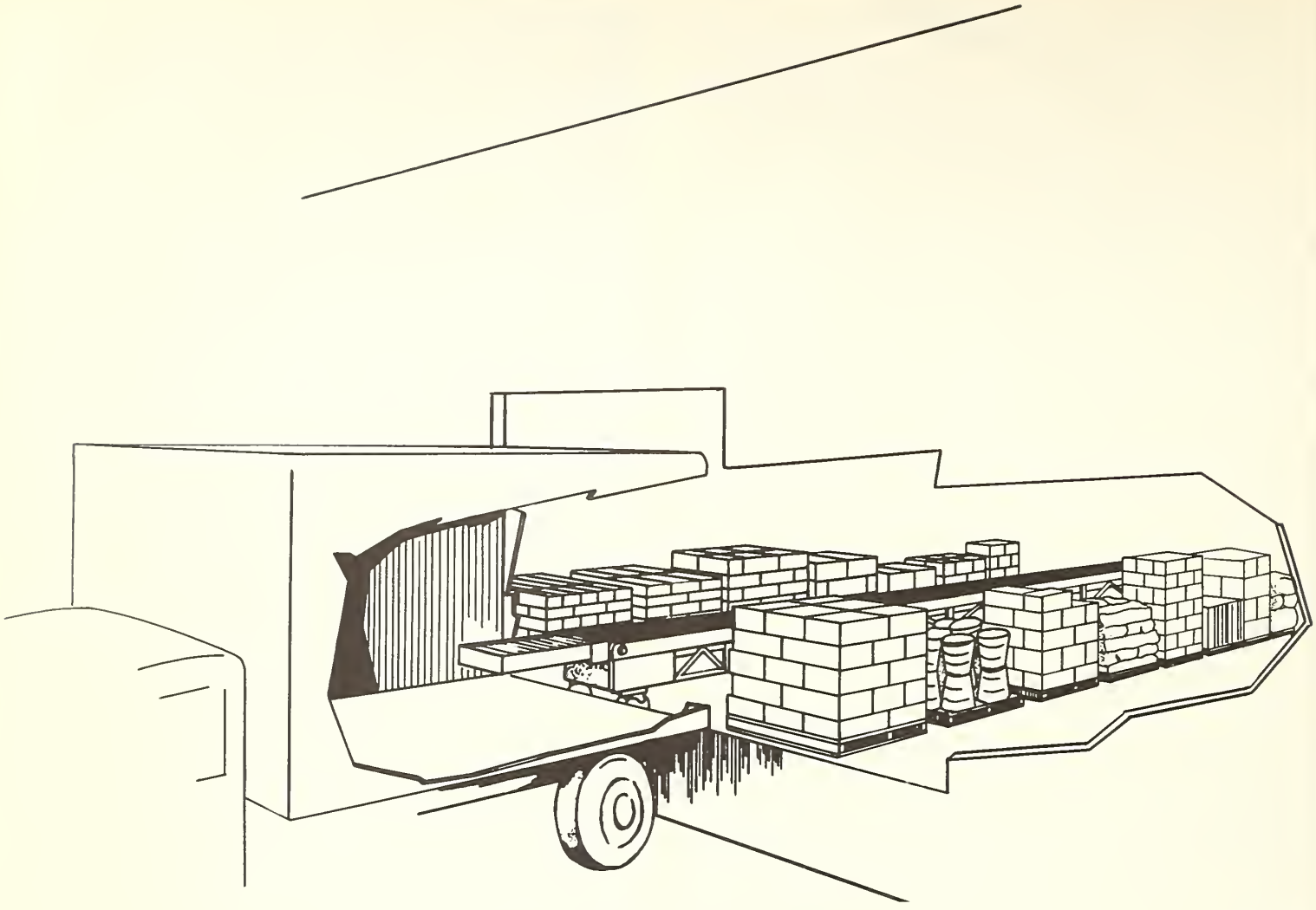

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FIGURE 6.—*Typical order assembly area.*

office unit. Floor area required would be at least 2,400 square feet.

Rail and truck platforms.—Platforms were designed for unloading both rail cars and highway trucks. Because shipments of fruits and vegetables by truck have increased yearly, truck access to the rail platform was planned. A 20-foot-wide platform was selected to provide a working aisle, 11 feet wide, for a forklift truck making a right-angle turn to pick up a loaded pallet. The rest of the platform width would be used to store empty pallets along the warehouse wall, to stack empty pallets adjacent to the carrier during unloading, to load a pallet on the platform when necessary, or to allow for the platform overhang of a bridgeplate extending into the carrier.

Equipment maintenance.—Modern electric equipment requires a separate service area. At least 400 square feet for parking the equipment, for chargers, for storing extra batteries, and for a hand-operated hoist to load and unload batteries was included in plans for the equipment area. A workbench and a place to store small parts were also provided.

Heating and refrigeration equipment.—Heating and cooling loads affect the size of the units to be provided. These in turn affect the floor area allocated to this service function of the warehouse. Boilers to heat the warehouse and to provide steam for the banana ripening rooms, as well as compressors, condensers, and allied equipment for refrigeration, would be located in this component. Enough additional space should be provided for equipment needed for the expanded warehouse. A minimum of 1,300 square feet of floor area would be required.

WAREHOUSE LAYOUTS

After the warehouse components and their area requirements were determined (table 2), the next step was to arrange the components for efficient warehousing. Maximum use of space, direct flow of commodities both in and out, and provision for future expansion were incorporated in the plans as well as the other layout principles discussed in this report.

More than one efficient layout can be developed. For that reason this report presents 3 plans for a service wholesale warehouse, to handle an annual volume of 1,000 carload equivalents and to be expandable to 2,000 carloads.

The first layout is for a square building, called the square layout in this report although the shape is rectangular after expansion. The second layout presents the best combination of components and a building whose outside dimensions are determined by that combination. This is called the unrestricted layout. The third layout was planned to simulate an existing multistore building altered for a representative service wholesale business. Rather than developing a layout with few or no dimensional limitations, this approach visualized the development of a layout within an existing structure. Later reference to this will be indicated as the multistore layout.

Handling operations, on which these layouts were based, require that receipts be palletized on the rail or truck platforms and moved directly to their designated storage areas.

TABLE 2.—*Area requirements for 3 proposed fruit and vegetable warehouse layouts by components*

Warehouse component	Square layout		Unrestricted layout		Multistore layout	
	Initial area	Expanded area	Initial area	Expanded area	Initial area	Expanded area
	Square feet	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*
General storage [1]	4,033	8,147	4,037	8,134	3,904	7,832
Prepackaging	2,074	4,149	1,988	3,957	2,098	4,032
Aisles and corridor	9,105	15,711	9,488	16,954	6,561	10,946
Dry cold storage [2]	1,823	3,647	1,714	3,428	1,605	3,275
Wet cold storage [2]	1,823	3,647	1,714	3,428	1,670	3,210
Banana ripening	1,204	2,408	1,204	2,408	1,264	2,528
Banana cutting and packing	1,129	2,299	1,142	2,276	914	914
Equipment repair	447	447	396	396	294	294
General offices:						
First floor	2,429	2,429	2,642	2,642	830	830
Second floor		1,951		2,674	2,182	3,668
Incinerator					252	252
Mechanical equipment	1,842	1,842	1,310	1,310	1,380	1,380
Partitions	1,800	2,814	1,649	2,734	2,016	2,991
Rail and truck docks	5,385	7,177	4,483	8,949	5,309	8,285
Supply storage	2,393	2,383	969	2,335	1,286	[3] 2,532
Tomato rooms [4]	(602)	1,314	602	1,204	(316)	1,213
Total	35,487	60,365	33,338	62,829	31,565	54,182

[1] Includes order assembly area.
[2] Includes area required for aisle inside room.
[3] Space for supply storage is over banana ripening rooms.
[4] Areas given in brackets are not included in totals. Space required has been included in supply storage.

During assembly, unit loads on pallets would be withdrawn from their respective storage areas and moved into position in the order assembly area. Palletized loads of packed boxes of bananas would be picked up from the banana cutting room or from a holding room. The portable belt conveyor with a retractable cantilevered extension would be used to move the commodities out of the warehouse and onto delivery trucks.

Space has been provided in each layout to store enough pallets for a 4½-day supply of fruits and vegetables. Aisles designed to service pallet storage areas are 11 feet wide. The only exceptions to this are the corridor and the aisle immediately in front of the wet and dry cold storage rooms. The latter aisle and the corridor are widened to accommodate a concentration of two-way traffic as well as to permit the maneuvering required to attain access to the cold storage rooms.

Commodities frequently moved in large quantities would be stored as close to the conveyor area as possible. In this way the cumulative distances traveled by the pallet transporting equipment would be minimized.

SQUARE LAYOUT

Railroad cars and trailer trucks can be positioned near any door opening onto the receiving platforms, shown at the back of the square layout (fig. 7), to minimize the distance pallets have to be moved. A refrigerated railroad car carrying apples, for example, could be spotted opposite the door to the dry cold storage room. As a result the maximum distance a loaded pallet would have to be moved would be less than 100 feet.

The small squares shown on each of the layouts represent pallet stacks. A pallet stack may consist of either a single loaded pallet or two loaded pallets tiered in storage position. Palletized commodities such as potatoes and onions can only be stored one-high. Other commodities such as apples and citrus can be tiered two high. The pallet designations clearly define the storage areas and their locations. The patterns indicated can be easily maintained by outlining each area with a painted or taped line. With storage points firmly established, the square layout provides for effective space utilization and minimum supervision for both labor and inventory control.

Product movement planned for this layout includes the movement of loaded pallets into storage, as described above, and also the direct movement of the same pallets, when needed, to the order assembly area. This area centers around the indicated conveyor. Four rows of 20 pallets each, stored 2 deep on each side of the conveyor, provide a storage bank of produce that is easily accessible for truckloading. The conveyor can be extended into the delivery truck to simplify the work.

The square layout makes it possible to receive produce at the rear of the building and move it directly to storage. When needed, pallet loads can be moved to a centrally located order assembly area for efficient truckloading at the front of the warehouse.

With the exception of the room set aside for the refrigeration units (mechanical equipment), all office and service areas were set off to the side of the warehouse to permit maximum use of warehouse space for handling. A typical internal layout for the general office area is shown in figure 8.

After expansion to handle an annual volume of 2,000 carload equivalents (fig. 9), the building is rectangular. Departure from the square shape was necessary to provide for expansion in one direction and to minimize expansion costs.

The net effect of expansion to 2,000 carloads annually is the doubling of storage space for the additional pallet loads, conveyor line, prepackaging equipment, and ripening rooms. The structure for the office area would be built initially to support a second story so that after expansion, new office space could be provided above that shown in figure 7. The mechanical equipment rooms (for refrigeration units) and boiler rooms would be large enough initially to provide space for extra equipment required to handle added cooling and heating loads.

In the initial design the outside wall from the mechanical equipment room to the cold storage room is nonbearing. The steel framework would be built and installed so that this wall section could be easily removed for ready access to the added warehouse area.

Should the service wholesaler elect to ripen green tomatoes as a part of his operation in the initial warehouse, then he could have one or two of the future banana rooms constructed for that purpose. As shown in figure 7, the future tomato room could be located in the general supply storage

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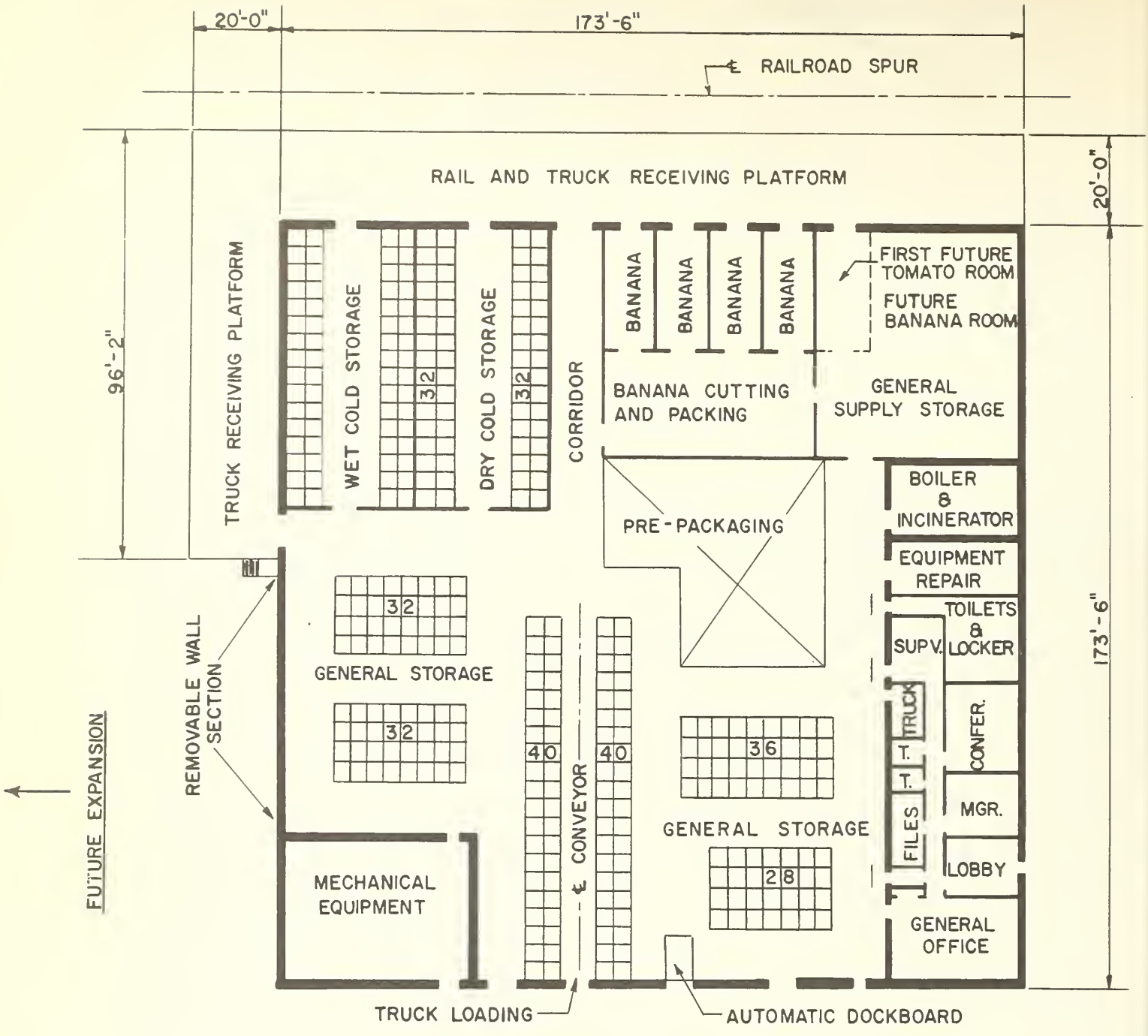

FIGURE 7.—*Square layout, initial.*

area. After expansion these tomato ripening rooms would revert to banana ripening. New tomato rooms would be built adjacent to the mechanical equipment room as shown in figure 9.

UNRESTRICTED LAYOUT

A layout plan was developed to provide the best combination of warehouse components for an efficient, highly flexible handling operation (fig. 10). This layout differs from the square layout (fig. 7) in three respects. First, the mechanical equipment and the boiler are in one room, next to the equipment repair and office area. As a result the office area is extended beyond the frontline of the warehouse itself. Second, the initial structure does not include the space for future banana operations. Structural provision was made for this phase of future expansion by making the outside wall of the initial banana cutting and packing room removable.

The building design also incorporates the necessary steel framework to permit removal of the exterior wall that runs from the initial general supply storage area to the cold storage rooms. This provision allows construction of the expanded warehouse (fig. 11) at minimum cost.

A third difference is in the layout plan for pallet stacks in the cold storage room. In the square layout (fig. 7), pallets are stored two deep on each side of the aisles in the cold storage rooms. In the unrestricted layout, pallets are stored three deep on one side and two deep on the other side of the aisle in each of the cold storage rooms. The advantage of the latter arrangement is to reduce the ratio of aisle space to storage space required in this low-temperature area.

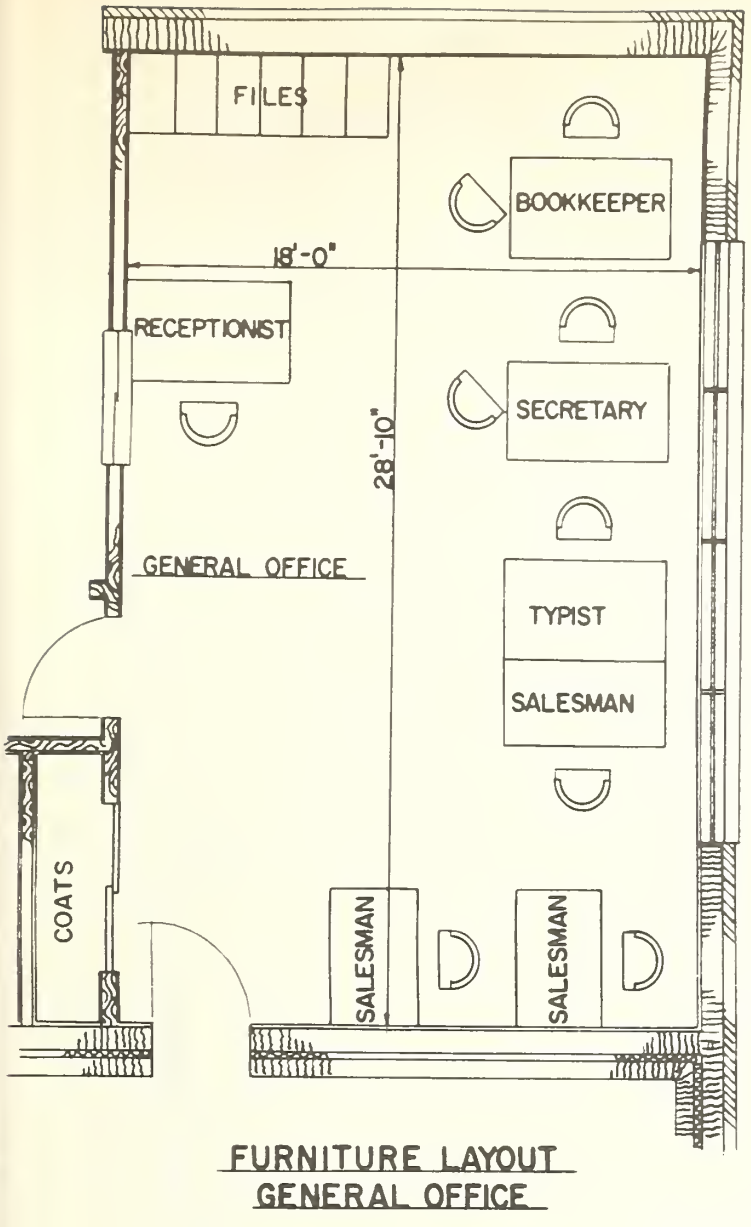

FIGURE 8.—*General office layout.*

The unrestricted layout is preferable to the square layout for a number of reasons. One is the fact already cited, that more effective use is made of cold storage space. A second factor is that the mechanical equipment room is outside of the main warehouse area. The layout is better balanced since the order assembly area is more centrally located. Locating the mechanical equipment room outside the main warehouse also makes it simpler to rearrange the layout to accommodate added operations, new handling methods, or new materials-handling equipment.

The irregular shape, initially, and the location of the mechanical equipment room will increase construction costs slightly. However, this small added cost would be compensated for by the greater flexibility in use of space and the reduced ratio of gross to net storage space in the cold storage rooms.

If a tomato ripening operation is to added, one or two rooms can be built adjacent to the office area and in front of the main warehouse. Lintels would be provided in the initial construction so that door openings could be cut in the outside wall of the warehouse with a minimum of remodeling.

MULTISTORE LAYOUT

The third layout was the most restrictive. The general framework of a modern multistore building was used as the shape in which the layout was to be developed. A maximum depth of 100 feet was specified. Needed floor area for handling annual volumes of 1,000 and 2,000 carloads had to be obtained by extending the length of the building while its depth was held constant. Some wholesalers might want to consider the alternative of increasing the depth of several store units with new construction to avoid the long, narrow layout that results within the existing framework.

Figure 12 illustrates a store unit in a modern multistore building. In the layouts that follow, a rear platform width of 16 feet was assumed to accommodate a fork truck and pallet operation. It was further assumed that the wide front platform would be completely enclosed. The original platform canopy structure might have to be reinforced, but its existing height would be utilized. Warehouse components that do not require high ceilings would be located there to minimize the total number of store units required.

Figure 13 shows the multistore layout for a 1,000-carload service wholesale business. This plan requires 13 store units, each 22½ feet wide.

The various warehouse components were arranged to keep the distances that commodities had to be moved as short as the length of the building would permit. Conveyors for truckloading were located so that movement from storage to the conveyor line was kept to a minimum.

Supply storage, boiler and mechanical equipment rooms, equipment repair area, a small truck-receiving dock, a supervisor's office, and toilet facilities for warehouse personnel were located on the former front platform. None of those components required a high ceiling. A portion of the general storage area extends out to the enclosed front platform. Pallet loads stacked only one high would be placed in that section. Additional office space would be built over the former platform area.

The pallet layout in the cold storage room calls for two rows, three deep, one on each side of a 10-foot aisle. Aisle width is 10 feet rather than 11 feet because of restrictions imposed by the existing structure. It is the bare minimum in which the average forklift truck can maneuver. It will slow the handling operation somewhat. However, it was felt to be a reasonable compromise. The aisle directly in front of the cold storage rooms and prepackaging area is 14 feet wide because of the heavy traffic to be handled there.

If tomato ripening is done, one or two of the future banana rooms would be constructed initially. After expansion (fig. 14) new tomato ripening rooms would be constructed in the added space.

The layout for 2,000 carloads (fig. 14) increases the building length and requires the addition of 8 store units. The space for supply storage would be eliminated because of the construction of additional banana rooms. However, the high ceiling over the original banana rooms would provide adequate space for supply storage. Prepackaging and storage areas are doubled to accommodate the added equipment and larger volumes to be stored.

The layouts illustrated in figures 13 and 14 are efficient, workable plans for a service wholesale warehousing operation in a multistore building. However, due to the long, narrow shape of the building, longer transportation distances, irregular paths of travel, and some cramped space, less efficient operating conditions have to be accepted. In both layouts a few pallet storage locations along the belt conveyor would have to be used to store items for which space is not available in general storage.

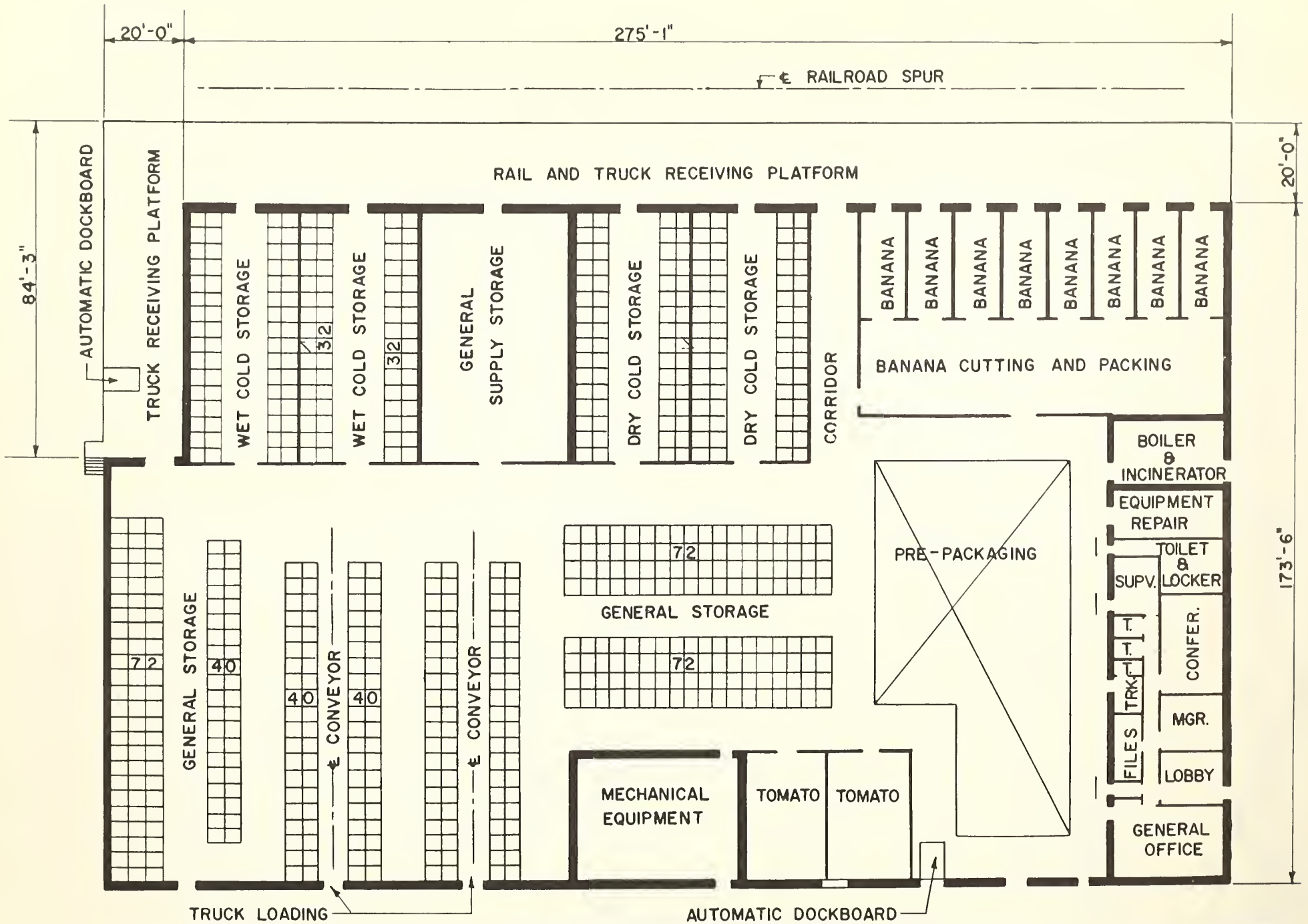

FIGURE 9.—*Square layout, expanded.*

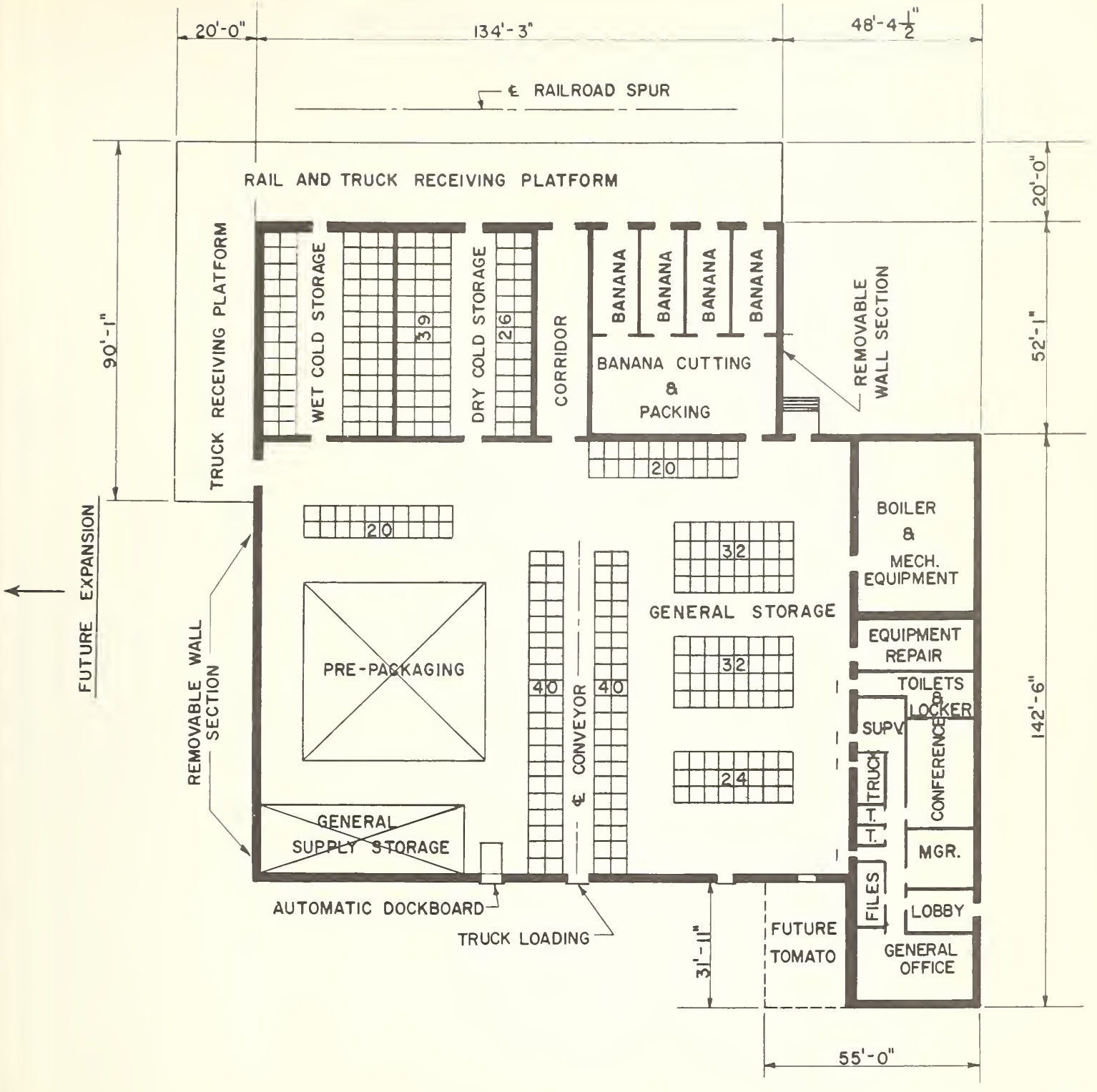

FIGURE 10.—*Unrestricted layout, initial.*

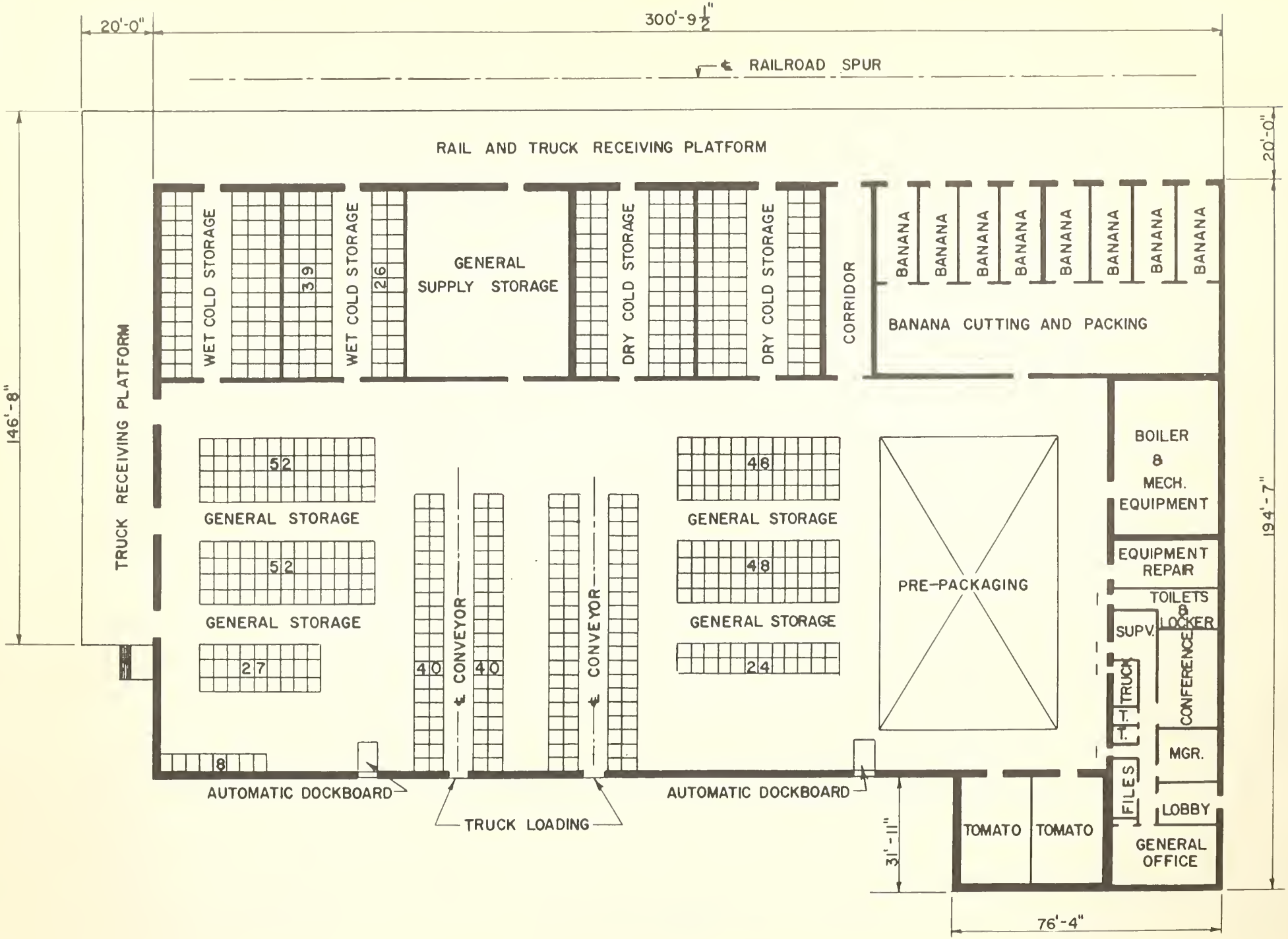

FIGURE 11.—*Unrestricted layout, expanded.*

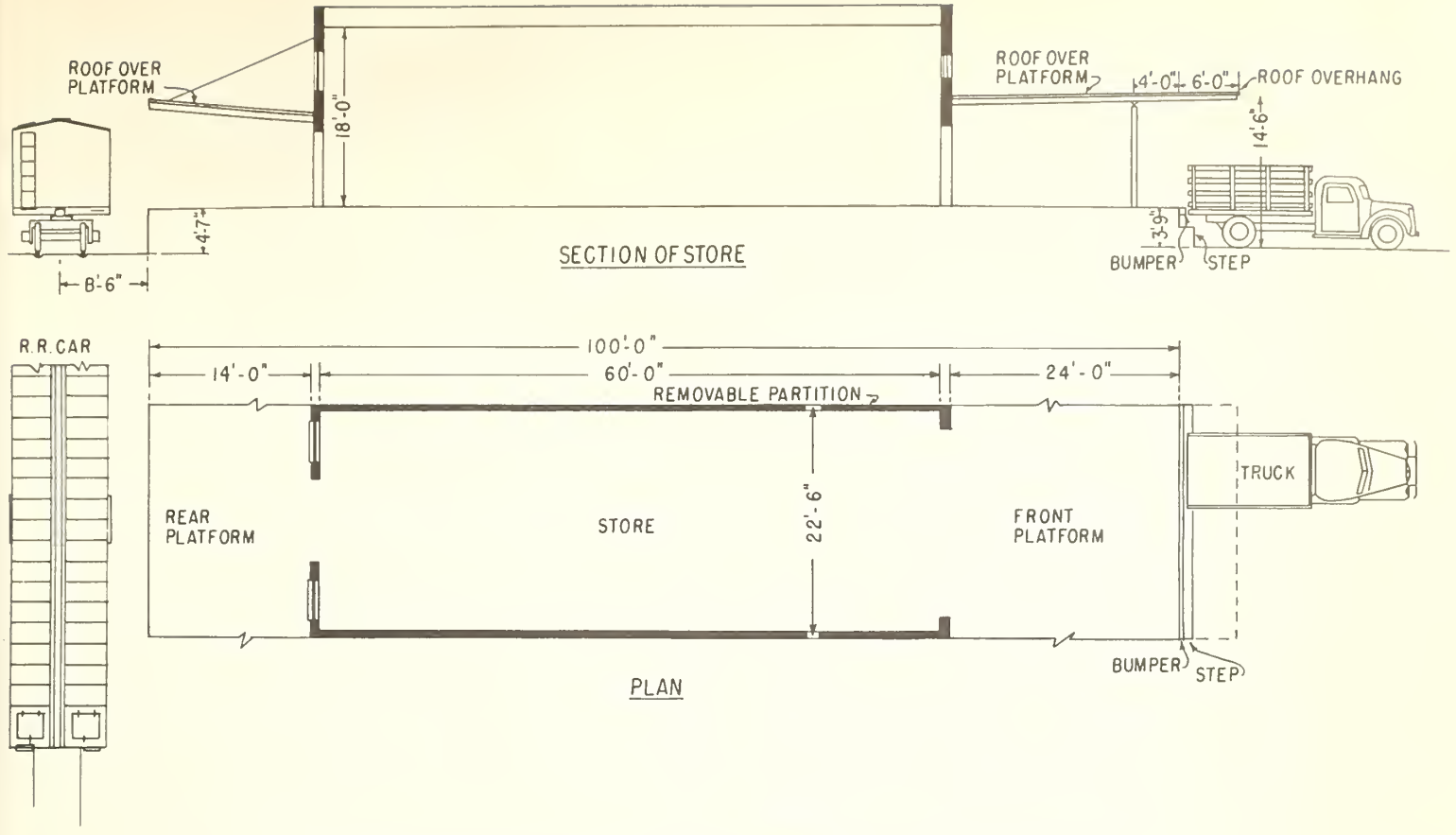

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FIGURE 12.—*Typical plan and elevation of a store unit in a multistore building.*

Although structural changes could be made to permit free and efficient movement of commodities through the warehouse, the cost might not be justified. For example, column spacing that would be desirable for individual store units might interfere with storage patterns and commodity movement when the units were combined to make a single warehouse. It would not be economically feasible to change a basic column plan. For another example, a narrow rear platform would need to be made at least 16 feet wide to accommodate forklift truck operation. Enlarging a rear platform would be expensive, not only because of the structural work but also because the railroad track would have to be relocated.

Other alternatives might be considered in remodeling a group of store units. For example, floor area could be expanded by adding a section 30 feet deep along the front of the building. Warehouse components could then be rearranged to provide shorter transportation distances and more centralized warehousing activities. For handling the initial volume the number of store units required could be reduced to approximately 10, and for the expanded volume, to approximately 16.

Wholesalers might give some consideration to the possibility of modifying the initial construction of a group of store units in anticipation of their future use for a service wholesale operation. Columns could be spaced to provide wide bays permitting maximum flexibility in utilizing floorspace. Floors, footings, columns, and other structural components could be designed to carry the loads of future construction. These loads would include new masonry walls, an office mezzanine, materials-handling equipment, and a strong roof over areas not previously enclosed. Floor, roof, and wall insulation could be included to avoid the higher cost of installation later.

ALTERNATE LAYOUT PLANS

A well-designed warehouse should permit more than one location for pallets and for materials-handling equipment. Belt conveyors, though movable, are frequently considered to be semipermanently located. Many service wholesalers have found that once a layout plan has been established there is little advantage in moving conveyor equipment. However, this semipermanent location does not preclude internal rearrangement of the general storage and order assembly areas.

In each of the warehouse layouts the assembly procedure is one in which complete unit loads of commodities are moved from storage to the order assembly areas. Trucks are loaded on a production-line basis by calling for items indicated on customers' invoices. Invoices are grouped for each truck.

In an alternate and equally efficient assembly and truckloading operation, the items to be shipped on four or more trucks are taken out of storage at the same time. The combined recapitulation of items for more than one truckload is referred to as a "group recap." In the order assembly area the commodities are divided into individual truckloads by accumulating items for one truck on one side of a conveyor and those for a second truck on the other. A second conveyor line is needed for the other two truckloads. These conveyors should be about half as long as those required for the production-line truckloading system described above. The group recap system can be as efficient as the production line, if the recorder and transcriber system described in earlier publications (*4, 8*) is used.

Figures 15, 16, and 17 illustrate the layout plan in which two short conveyor lines are used in conjunction with the group recap system. For the multistore building, this layout is an improvement since flow lines are substantially less distorted by the shorter conveyors.

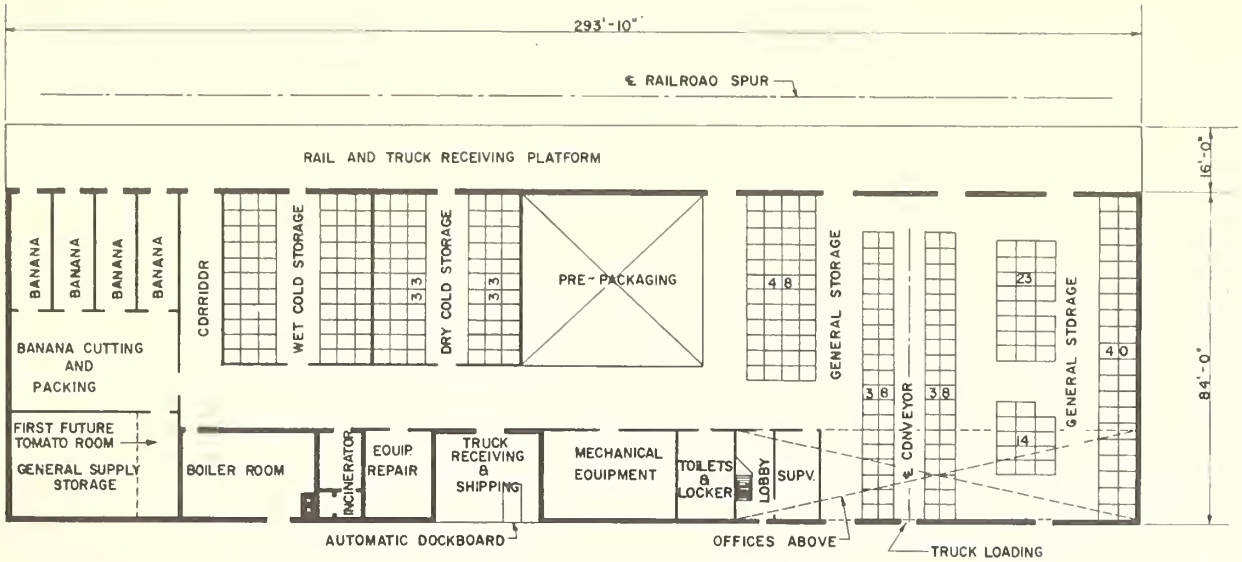

FIGURE 13.—*Multistore layout, initial.* 7221–59(5)

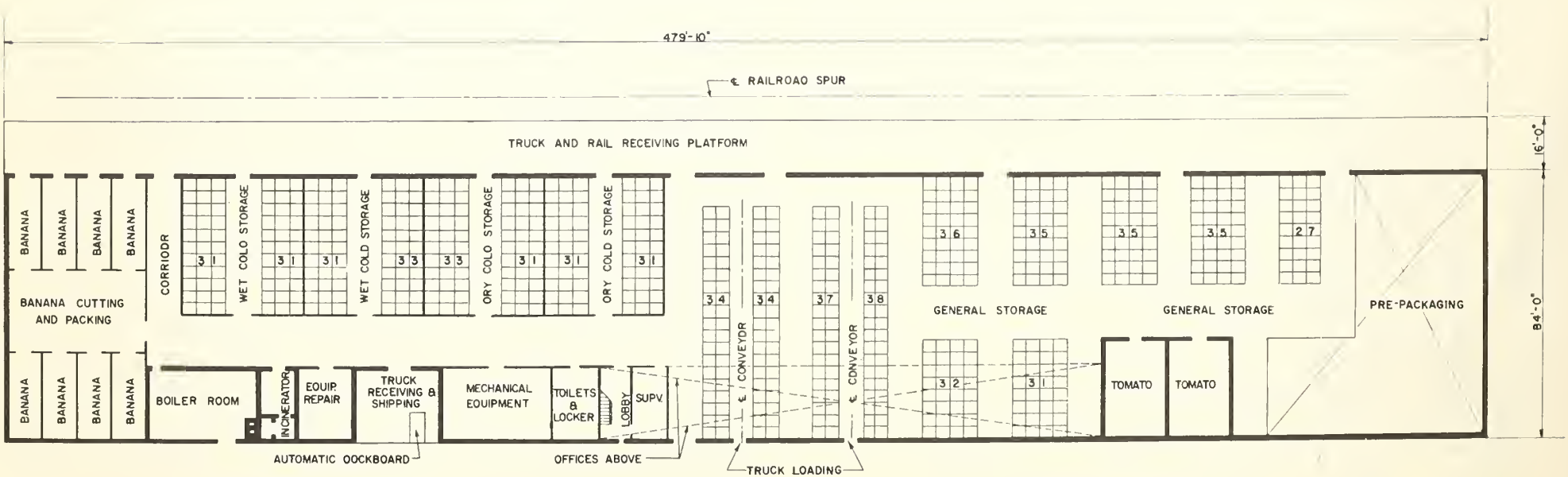

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FIGURE 14.—*Multistore layout, expanded.*

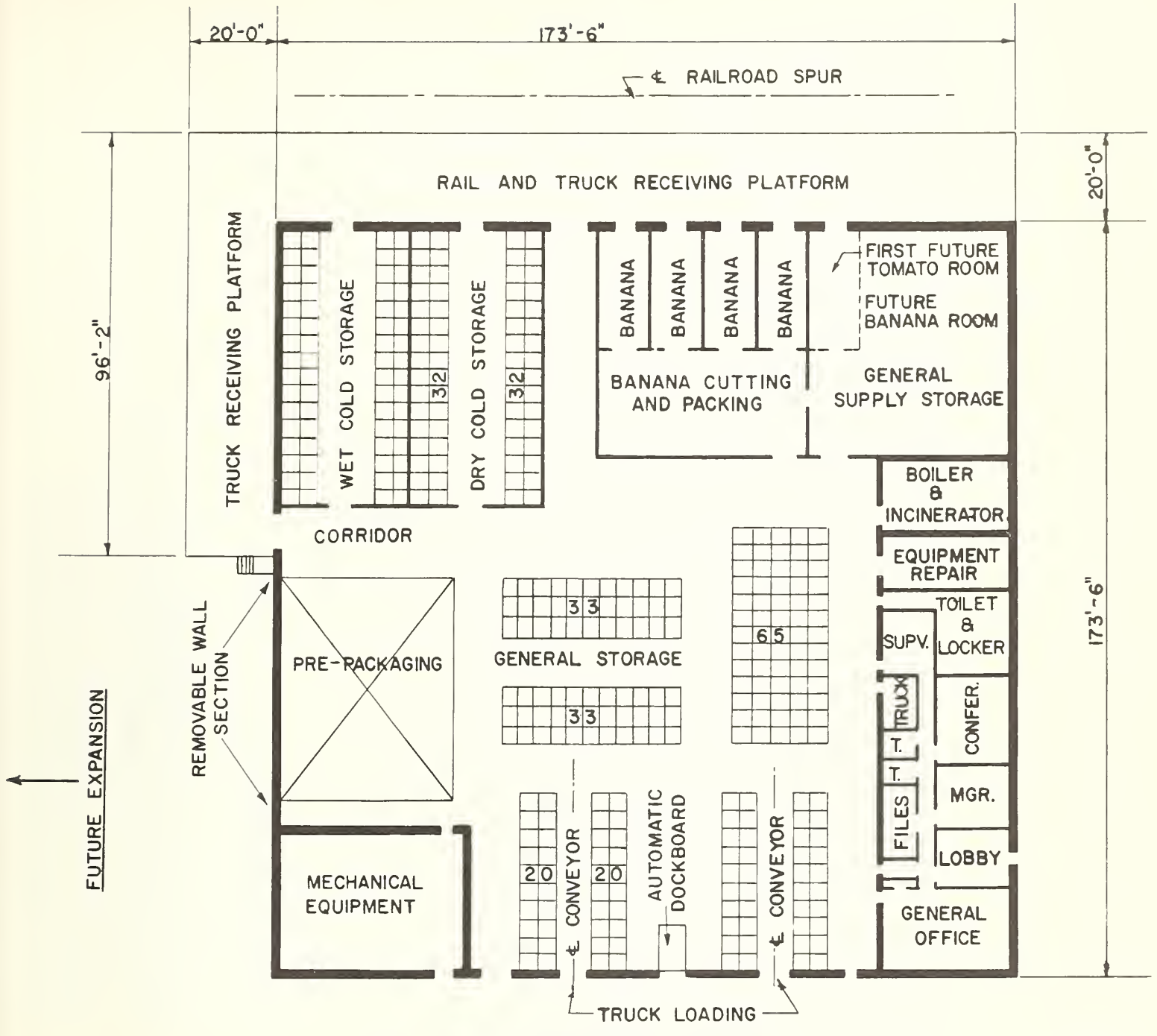

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FIGURE 15.—*Square layout with two short conveyors.*

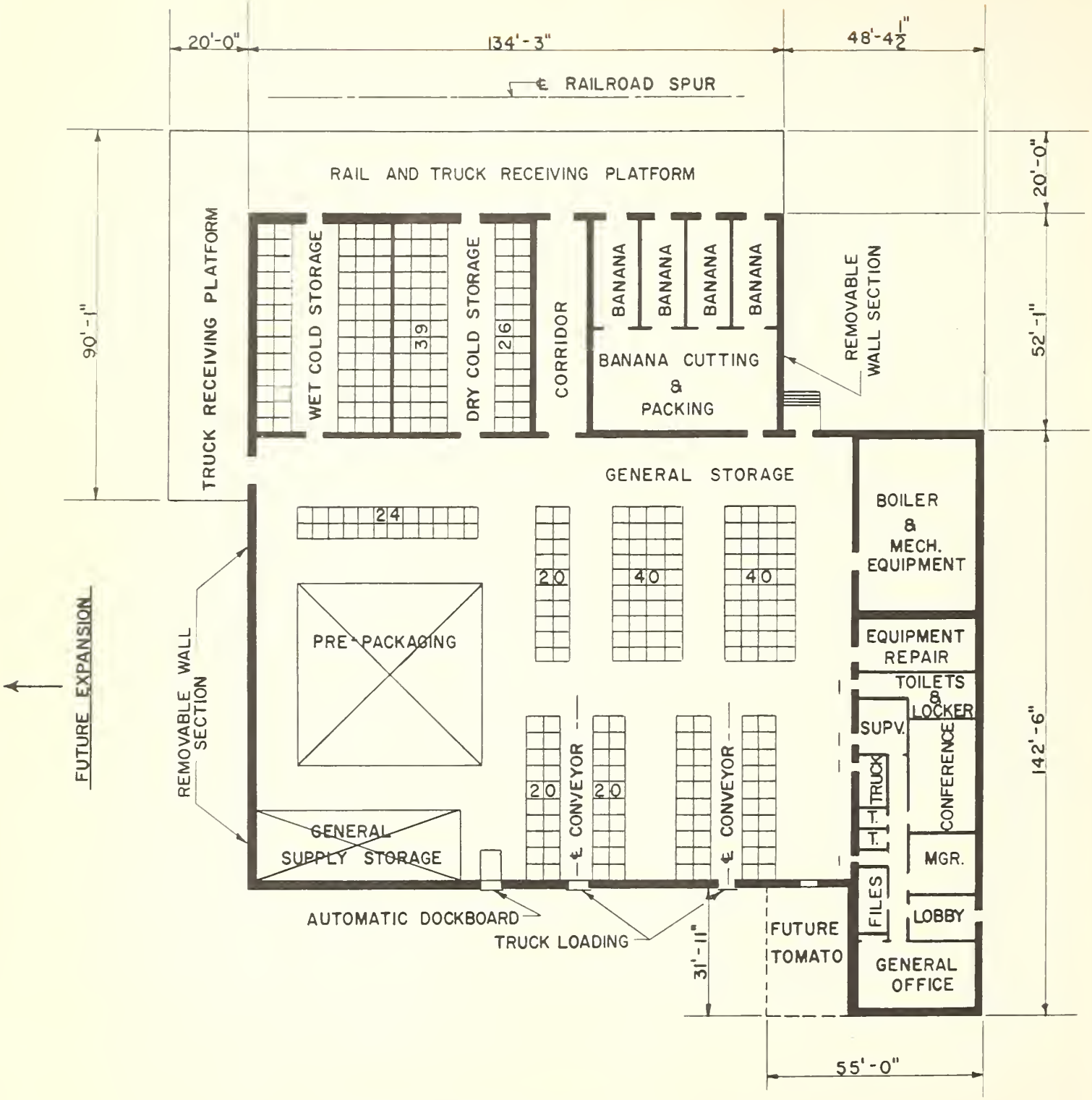

FIGURE 16.—*Unrestricted layout with two short conveyors.*

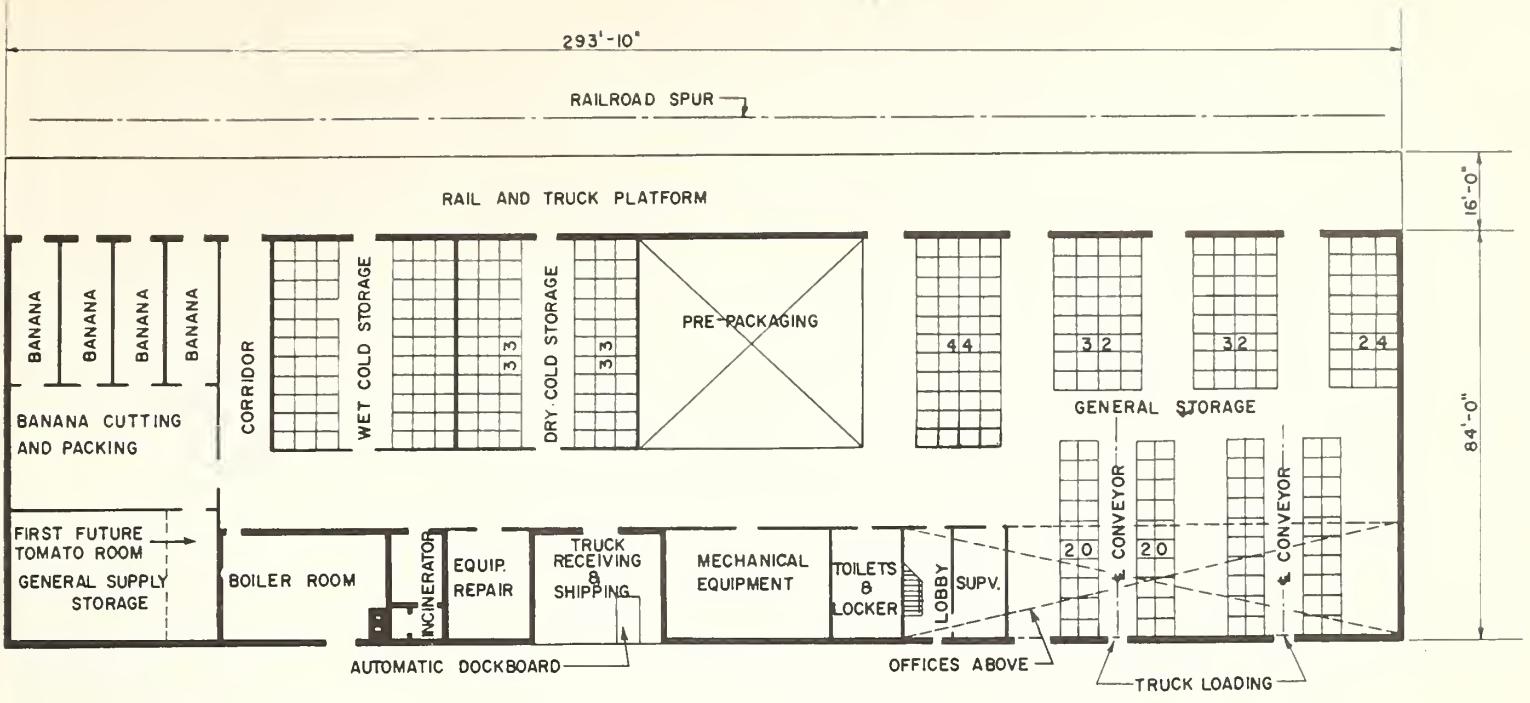

FIGURE 17.—*Multistore layout with two short conveyors.*

WAREHOUSE DESIGN FOR THE UNRESTRICTED LAYOUT

Many service wholesale warehouses designed around an efficient layout have been built in recent years. However, failure to provide proper ceiling clearances, adequate doors, floor drains, and other important features has sometimes resulted in a warehouse less efficient than it could have been. Mistakes made during construction can increase operating costs unnecessarily. Frequently this extra cost has to be borne for the life of the facility.

After the layout plan has been fully developed and approved, detailed design drawings and specifications are required before construction can begin. The initial stage of the unrestricted layout (fig. 10) was selected for detailed analysis in this report. Design drawings were prepared to give specific information on structural features, fixtures, and other details that make it possible to operate a given materials-handling system in the most efficient manner possible.

In addition to features that permit efficient warehouse operations, consideration was given to the effects of climate represented by three different geographical locations. The cities of Cincinnati, Ohio, New Orleas, La., and Minneapolis-St. Paul, Minn., were selected to give a wide range of weather and temperature. Design drawings and specifications were developed for each of these cities for a service wholesale warehouse with a capacity for 1,000 carload equivalents annually.[3]

CINCINNATI, OHIO

The warehouse proposed for Cincinnati is a single-story, steel frame building, approximately 28,290 square feet in overall area with an additional 4,490 square feet of truck and rail receiving platforms. Exterior walls are non-load-bearing masonry with temporary end walls of wood frame and metal siding; interior partitions are concrete masonry and wood stud types. The floors are concrete slab on gravel. Concrete in the storage areas and on platforms has nonslip finish. Roof decking is metal with a 20-year bonded, built-up covering over insulation. The exterior walls are insulated, except those around the offices, boiler room, and mechanical equipment room. Figure 18 provides an illustration in perspective of the warehouse building.

Site Plan

A lot that would have adequate space for both initial and future construction for the proposed warehouse is shown in figure 19. The fence line shows the lot boundaries and encloses an area of approximately 5½ acres. The fence gate is set back to permit temporary offstreet parking for a truck if the gate is closed when it arrives at the warehouse.

The site plan shows access roads, truck maneuvering aprons, and parking areas. Access roads are 24 feet wide to permit safe two-way traffic as required. The truck aprons at loading platforms provide 100 feet of clear area in front of the platforms for maneuvering of trucks (*7*, *14*). Aprons at both the truck and rail docks make the entire length of receiving platforms accessible for truck deliveries. The aprons have concrete strips so trailers can be uncoupled from tractors and parked for unloading without having the steel dolly wheels damage the pavement.

The parking area for trucks and trailers is 182 feet 8 inches long by 35 feet wide. It is large enough to accommodate 16 trucks or trailers. Parking space for employees and visitors is adjacent to the office section of the warehouse. It is 76 feet wide by 100 feet long and provides two rows of parking.

The site should be graded so that the three truck maneuvering aprons will be level. Steeper slopes than adequate drainage requires will interfere with efficient loading and unloading of trucks.

Floor Plan

The floor plan for the warehouse designed for the climatic area represented by Cincinnati is shown in figure 20.

[3] Detailed design drawings and specifications for each location can be obtained for the cost of reproduction and handling. For price list, write to Cooper-Trent Blueprint & Microfilm Co., 2701 Wilson Boulevard, Arlington 1, Va.

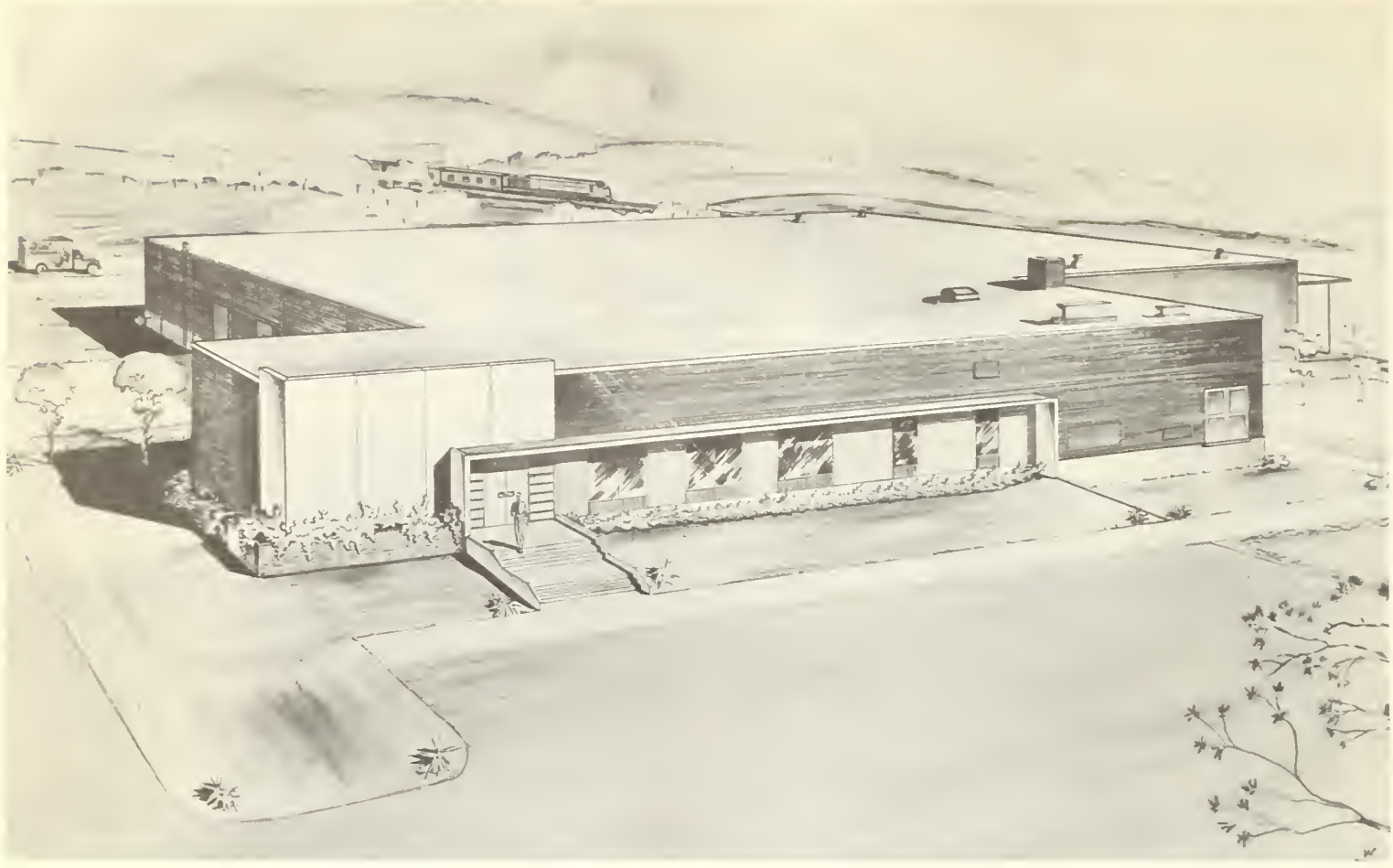

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FIGURE 18.—*Perspective of proposed warehouse.*

Rail receiving platform.—The rail receiving platform is 154 feet long and 20 feet wide. It provides space for four refrigerator cars. During the peak business period, average weekly receipts by rail would be 10 carloads. With daily track service available, 10 cars a week can be accommodated easily.

Platform height above the rail is 4 feet 7 inches to permit access to refrigerator cars on bridge plates that are approximately horizontal. As a result cars can be unloaded expeditiously and safely.

When the platform is at this height the centerline of the spur track should be set away from the face of the platform at least 8 feet so that hinged doors on the older refrigerator cars can be opened.

The area in front of this platform should be surfaced so that truck deliveries can be made when it is not fully occupied by refrigerator cars.

Truck receiving platform.—A 70-foot platform, 20 feet wide, is provided to receive most of the trucks. This platform has adequate space to unload seven tractor trailers. It should be 4 feet above the pavement. This height is a satisfactory average for most trailer trucks, although truck heights may vary because of differences in weight of loads, size of tires, and other factors. Columns supporting an overhanging canopy are set back 4 feet from the platform edge to permit trailer doors to be opened after they have been backed into position (*3, 5*).

Some receipts can be handled at the truckloading side of the warehouse where the automatic dockboard is indicated. The dockboard is set 3 feet 9 inches above the pavement. It can be raised 16 inches or lowered 12 inches from that height. As a result it will accommodate a wide range of truckbed heights. When not used for receiving it can be used for loading small orders on delivery trucks.

Doors and door openings.—Quick, unhampered movement of commodities into and out of warehouse storage areas is an important feature in efficient handling. Door openings therefore were designed to accommodate the full width of a loaded 48- by 40-inch pallet and the height of a forklift truck. Minimum dimensions selected for the doors were a width of 72 inches and a height of 89 inches. A pallet that is 43 inches wide, including overlap, would have a 14½-inch clearance on each side as it moved through the door. The load can be moved through such an opening quickly and smoothly. Chance of snagging containers against the door frame or damaging packages would be avoided.

Power-operated doors that slide horizontally are used in openings to wet and dry cold storage and from the rail and truck receiving platforms into the general storage areas. Since all these areas are held at controlled temperatures, power-operated doors minimize loss of cooling resulting from the introduction of outside air. Controls activating the doors are suspended from the ceiling or canopy so the fork truck operator can open and close the doors without leaving his equipment.

Doors on the truckloading side of the warehouse are the horizontal sliding type but they are not power operated. Doors opening to the banana ripening rooms are smaller since they are designed to accommodate a four-wheel banana truck with a superstructure. Hinged doors that swing open are used for the ripening rooms since these rooms are entered less often than other storage areas.

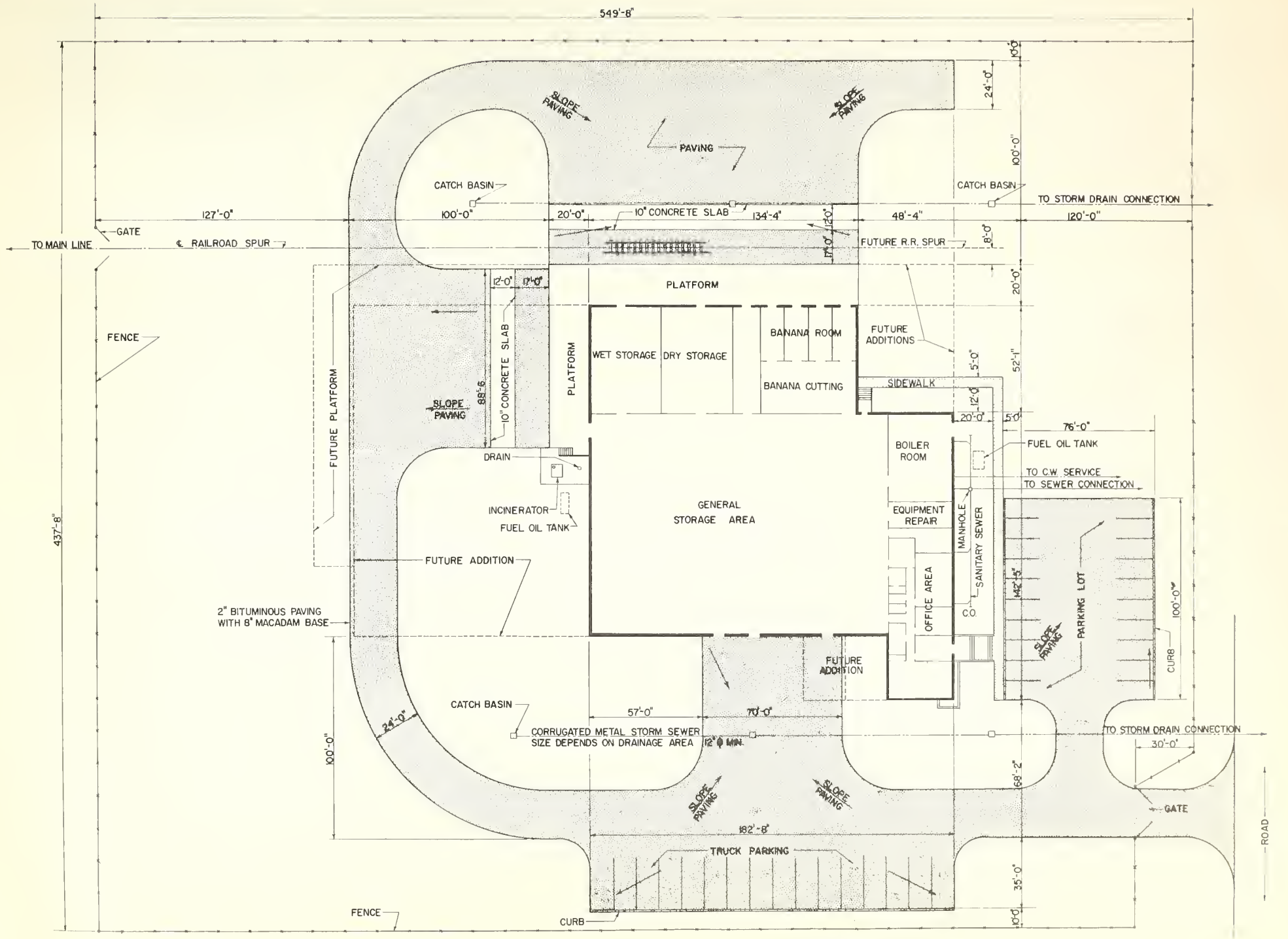

FIGURE 19.—*Site plan.*

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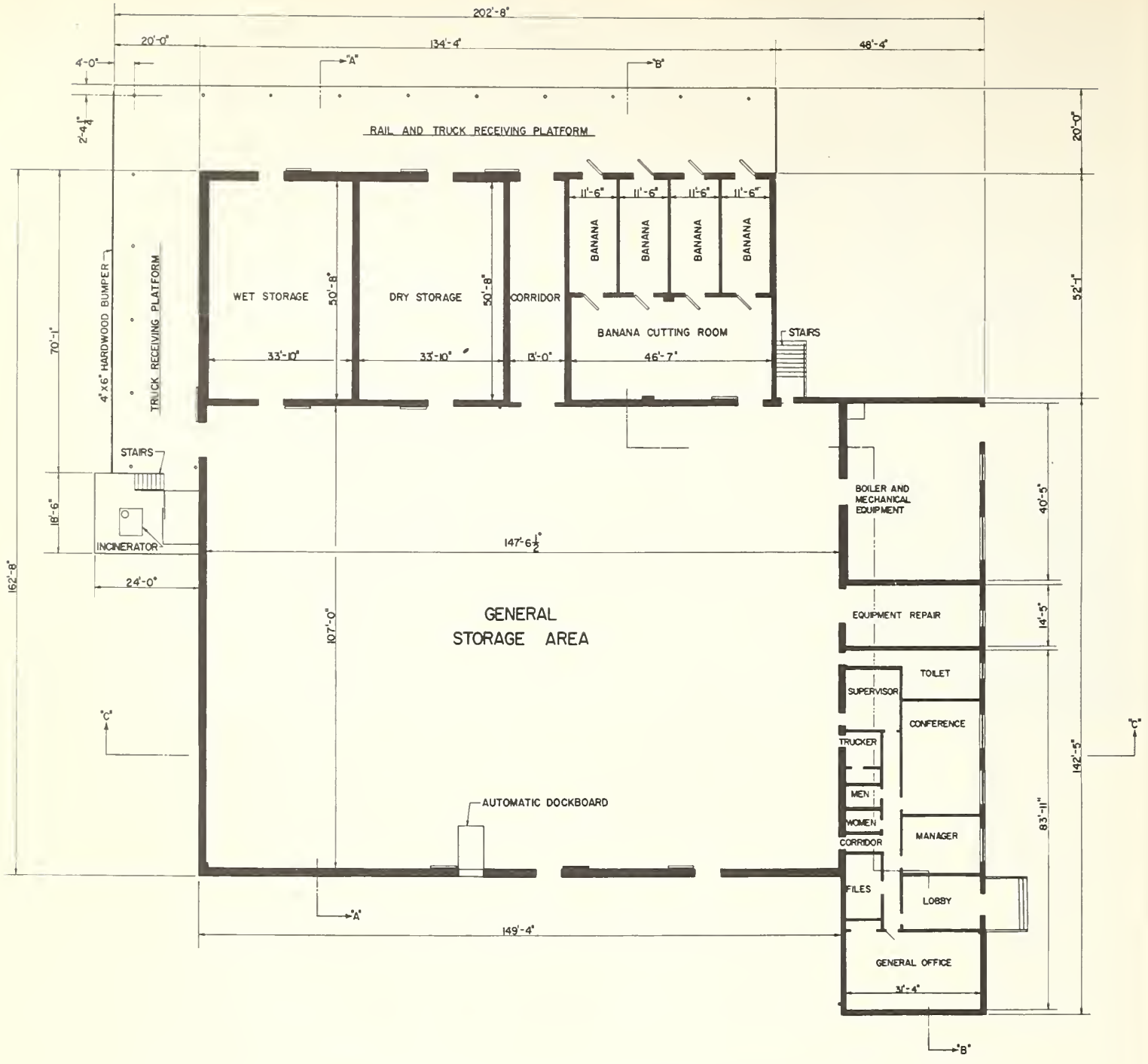

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FIGURE 20.—*Floor plan of proposed warehouse in Cincinnati, Ohio.*

Dimensions of the principal door openings are shown in table 3.

TABLE 3.—*Dimensions of principal door openings in a proposed wholesale fruit and vegetable warehouse, Cincinnati, Ohio* [1]

Type and location of doors	Width	Height
Sliding doors:		
Rail and truck platforms	8′ 0″	7′ 5″
Dry and wet cold storage rooms	6′ 0″	7′ 5″
Truck loading side	6′ 0″	7′ 4″
Hinged doors: Banana ripening rooms	5′ 0″	6′ 6″

[1] Complete details can be obtained from design drawings and specifications. (See footnote 3, p. 17.)

Walls and partitions.—Exterior walls, except those around the office, boiler, and equipment sections, are insulated. The walls are clay or shale brick backed with a concrete masonry unit. Temporary insulated exterior walls to be removed in future expansion (fig. 19) are prefabricated, insulated metal panels on steel framing. Thickness of insulation varies from 3 to 5 inches depending upon location and temperatures to be maintained. Outside walls for dry and wet cold storage require the maximum thickness of insulation.

Various construction materials are used for interior walls and partitions. Hollow concrete masonry units are provided between the warehouse and offices, toilets, boiler room, and equipment room. Wood studs with gypsum wallboard are used between offices and toilets.

Insulated surfaces are covered with concrete masonry or a protective plaster facing.

Knockout panels for future doors would be provided as needed for expansion as well as for alternative layout arrangements.

Floors.—The entire warehouse has a concrete slab floor poured on a gravel drainage fill. This construction has the advantages of low cost, long life, and higher load capacity than other floors. An abrasive is used for traction in warehouse and platform floor surfaces, to minimize risk of personal injuries or damage to materials-handling equipment. Although floor drains are provided throughout the warehouse, some standing water is unavoidable. The traction wheels on loaded handling equipment would slip easily on wet floors that did not have an abrasive surface.

In addition to providing a sound base under the floor slab, the gravel drainage fill furnishes some insulation from the earth below.

Dry and wet cold storage rooms.—Refrigeration equipment has the capacity to maintain the cold storage rooms at 32° F. and 85 to 95 percent relative humidity. The rooms have floor drains so they can be used interchangeably for wet or dry cold storage. A 4- by 4-inch wood curb runs lengthwise on each side of both rooms. The front face of the curb is 8 inches from the face of the wall. The curb acts as a pallet stop that prevents damage to the insulated walls and provides space between the load and the wall for air circulation.

Ceiling-hung unit coolers, equally spaced, are placed on each side of the partition dividing the cold storage rooms. Blowers in these units force cold air to circulate across the width of the room down the opposite side and back across the room. Separated pallet loads permit the most efficient air movement.

Banana ripening, cutting, and packing rooms.—Construction requirements for banana ripening rooms are similar to those for cold storage rooms. Temperatures and humidities to be maintained differ, however. The recommended temperature range for ripening is 56 to 68° F. A water spray system is included to maintain high humidity. Layouts and construction details for banana ripening rooms and specifications for ripening temperatures and humidities have been published earlier (*2, 6*). Electrical wiring in these rooms should be explosion proof since ethylene gas is often used to accelerate ripening.

The cutting and packing room is separated from the main warehouse to avoid interference with regular warehousing operations and to maintain temperatures most favorable to ripened bananas. Temperatures should be held between 56° and 60° F. in this room.

Boiler and mechanical equipment room.—The mechanical equipment room has space for the ammonia compressor and condensers needed to supply refrigerant to coolers in cold storage and general storage. Dichlorodifluoromethane compressors and condensers are provided for the banana ripening rooms. A low-pressure, oil-fired steam boiler in this area furnishes heat for the water vaporizing system used to ripen bananas and heat for all other warehouse areas as it is required. If gas fuel is cheaper than oil the heating system can be easily converted to gas. An air compressor is also included here to provide power to open and close all mechanically operated doors.

Equipment repair.—Supports for battery racks and chargers and for an overhead monorail hoist are provided in this space. Enough floor area is included to park unused power equipment. The monorail is designed to support a spur-geared, hand-chain-operated hoist with a 2-ton capacity plus a 25-percent impact load. The function of the hoist is to remove heavy storage batteries from the power-operated handling equipment for charging. A spare battery with a full charge would then be installed in the equipment.

Office and other areas.—Toilet facilities for warehouse personnel and office space for supervisory and clerical personnel are in the remaining section of the office and service area of the warehouse. A "packaged" air-conditioning unit heats and cools all office areas. The unit is hung from the ceiling of the equipment repair area with ductwork leading to all office areas serviced. Cooling capacity is approximately 7 tons.

Incinerator.—A portable, oil-fired incinerator is recommended. Gas fuel can be substituted if oil is more expensive or not available. The capacity would be 300 pounds of trash or garbage per hour. A portable type was chosen because it is big enough and it can be relocated with a minimum of expense when the warehouse is expanded.

Other features.—The corridor between the cold storage rooms and the banana ripening and cutting rooms is not cooled. It is shut off from the general storage area by swinging doors that control losses of cooled air to that area. An insulated, power-operated door closes off the corridor from the rail receiving platform.

Downspouts for roof drainage should be inset in outer walls. If the spouts are inset they will be protected against damage from power-operated handling equipment and from trucks.

Guard rails, installed opposite office doors that open into the warehouse, protect personnel from warehouse traffic.

A complete intercommunication system permits two-way communication in all warehouse areas and receiving platforms. Three master stations are provided in the office area with their exact location to be determined by the service wholesaler. Suggested locations are the telephone switchboard, the supervisor's office, and the owner-manager's office. Remote speaker stations have three switches to originate calls to the three master locations.

Fluorescent and incandescent interior lighting is provided, plus outside functional and security lighting. Fluorescent lights are used wherever they are practicable. They are more efficient, they produce a smaller refrigeration load, and they cost less to operate than incandescent lights.

Fixtures and illuminating levels were selected to suit each area. They range from incandescent units to provide about 15 foot-candles in the wet and dry cold storage rooms, through industrial fluorescent units to deliver approximately 15 foot-candles at floor level in the general storage area, to commercial fluorescent units to provide about 50 foot-candles on office desks.

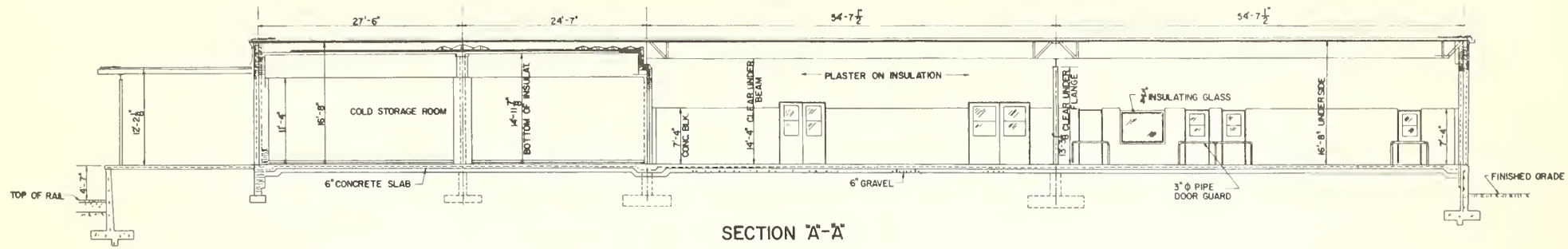
General Sections and Elevations

Figures 21 and 22 give additional dimensional information on the warehouse design. Figure 21 indicates three general sections that cut through the warehouse. The section lines are shown on the floor plan (fig. 20). Section A shows the vertical dimensions for the rail receiving platform, a cold storage room, and the general storage area. The doors to the boiler and equipment repair rooms and the offices can be seen in the background.

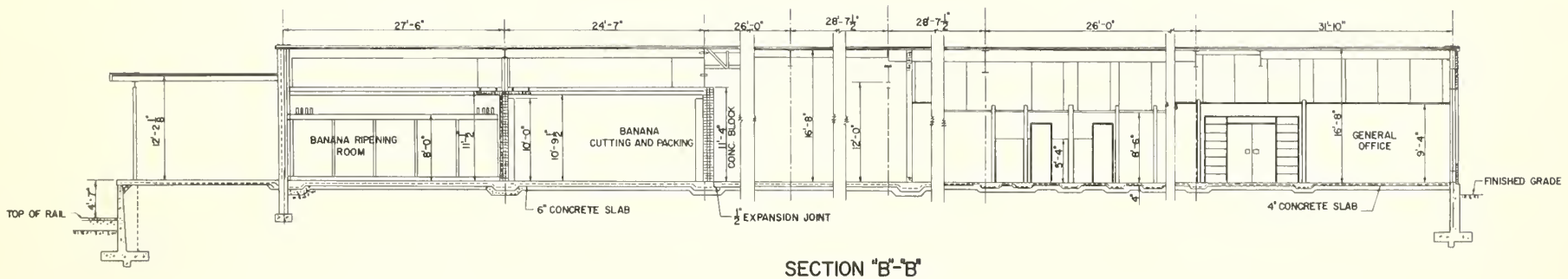
The lines for section B follow an irregular path as indicated in figure 20. The section starts on the rail platform and then shows interior details of a banana ripening room, boiler and mechanical equipment room, equipment repair room, toilets, lobby, and general office.

Section C cuts through the general storage area. It omits the truck receiving dock but shows the door openings for wet and dry cold storage, the corridor, banana cutting and packing room, and the door leading outside. The balance of the section cuts through the truckers' locker room, the office corridor, and the conference room.

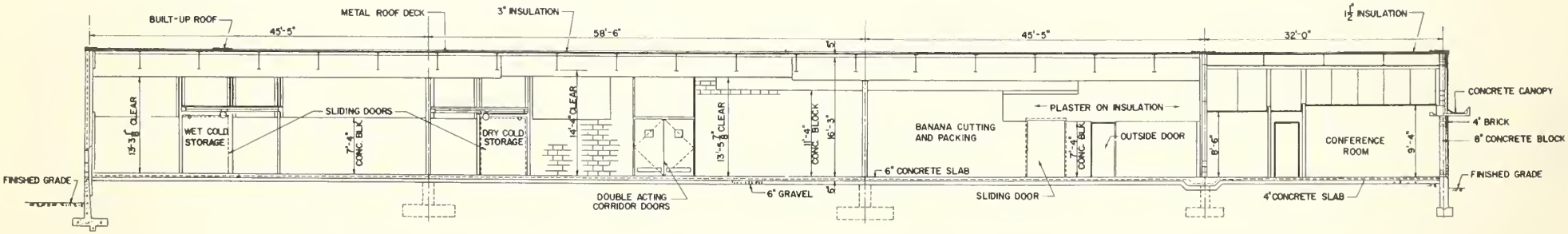
In the cold storage rooms and the general storage area all pipes, ducts, unit heaters and coolers, ductwork, and any other ceiling-hung equipment should be installed so that the lowest point of the unit is at least 12 feet above the warehouse floor. This 12-foot clearance is necessary to assure complete use of vertical space for tiering pallet loads of commodities. If this clearance is not maintained then pallet storage operations will be obstructed.



SECTION "A"-"A"



SECTION "B"-"B"



SECTION "C"-"C"

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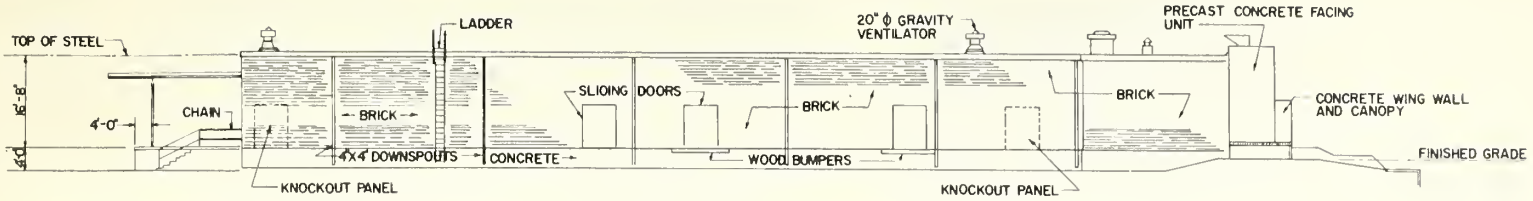
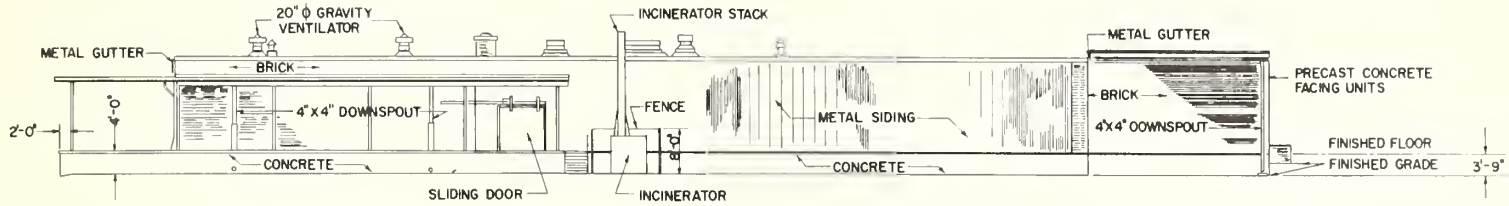
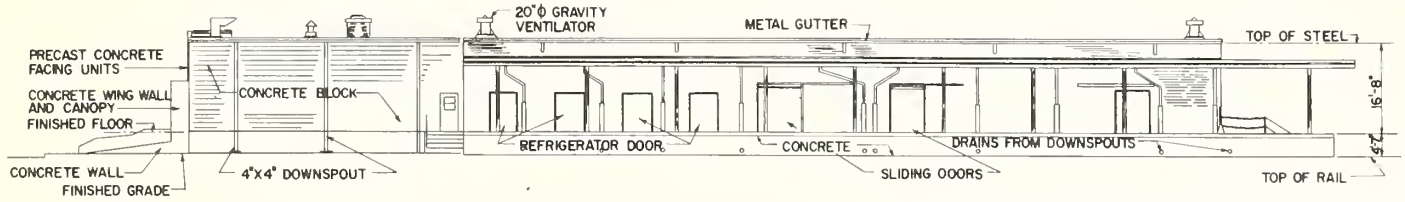
FIGURE 21.—*General sections.*



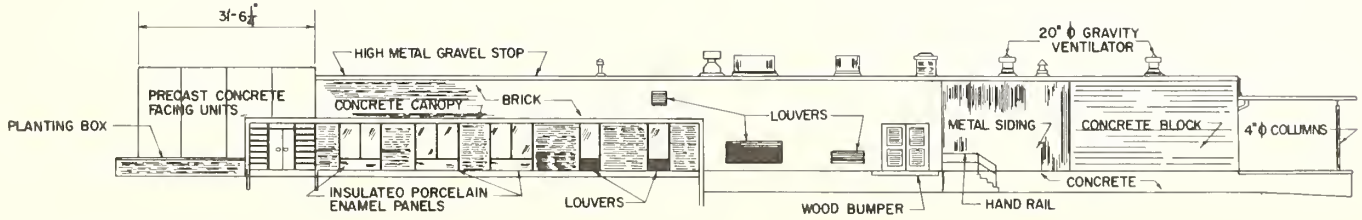
ELEVATION "A"



ELEVATION "B"



ELEVATION "C"



ELEVATION "D"

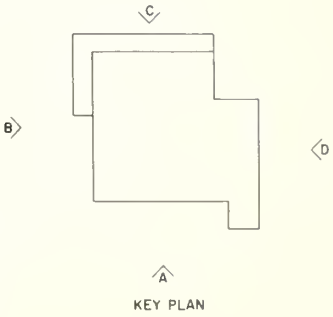


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FIGURE 22.—*Elevations.*

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FIGURE 23.—*Warehouse model, office and truckloading sides.*

The elevations in figure 22 indicate the vertical dimensions for the exterior of the warehouse. Openings for doors, windows, and ducts are shown as well as roof ventilators, chimneys, and so on. Elevation A shows the warehouse from the truckloading side; B shows the truck receiving side and the incinerator. Note the section of wall with metal sheeting. It is this portion of exterior wall that is to be removed for the purpose of expanding the warehouse at a future date. Elevation C shows the rail receiving side and the back of the office and service area. D shows the office and service area side. The section of metal siding is to be removed to expand the banana cutting and packing rooms when the warehouse is enlarged. Four banana ripening rooms would be added.

Warehouse Model

A three-dimensional scale model of the service wholesale warehouse was constructed when the specifications and design drawings were completed. The model provided a more realistic presentation of warehouse features and components than was otherwise possible. Figure 23 is a photograph of this model from the office and service area section and the truckloading side. The clear plastic roof reveals some of the interior features. Parking areas for visitors' and employees' cars and for delivery trucks can be seen. A delivery truck is shown in position for loading. Access roads around the warehouse are also clearly shown.

Figure 24 shows the warehouse from the rail and truck receiving sides. Road access to the rail dock can be seen. Trucks can be unloaded at this dock when three cars or less are on the spur. The paved white strip in front of the rail and truck docks represents the concrete surface for the steel dolly wheels of detached trailers that have been parked for unloading.

Figure 25 shows the interior of the warehouse. At the left the incinerator can be seen, as well as a forklift truck picking up a loaded pallet from a truck. The number of pallet loads shown in the storage area was limited to one-third of the capacity so that warehouse features could be more readily seen.

The four white blocks shown on the ceiling of each cold storage room represent the unit coolers. The cutaway view of the banana ripening rooms shows some of the details of construction and the location of the unit heaters and coolers above the beams used to hang banana bunches. A cutting table and a four-wheel banana truck can be seen in the lower right corner of the banana cutting and packing room.

The boiler and mechanical equipment room shows location of the boiler, compressors, condensers, and auxiliary equipment. The workbench in the equipment repair room can also be seen. The locker rooms, toilets, conference room, and other offices with their equipment are also indicated.

The belt conveyor is in its place at the center of the order assembly area in the general storage section of the warehouse. The extendable end section of the conveyor has been run into the delivery truck which is being loaded. Unit pallet loads beside the conveyor are available for order picking as required by customer invoices.

The shaded part of the general storage area represents the section set aside for prepackaging. The pallet loads show the portion of the general storage area set aside for pallet storage. The fingerlike ducts shown fastened to the warehouse roof are used to distribute refrigerated air through this part of the warehouse. Four of the eight duct fingers have been cut away so that features below can be seen.

ALTERNATE LOCATONS

New Orleans, La., and Minneapolis-St. Paul, Minn., were selected for alternate warehouse designs because these cities represent a warmer and a colder climate than that of Cincinnati. Outside temperatures at each location are shown in table 4. These temperatures were the basis for determining

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FIGURE 24.—*Warehouse model, rail and truck receiving sides.*

heating and refrigerating loads. Summer dry-bulb temperatures were identical for each location. Wet-bulb temperature in New Orleans was 2° above Cincinnati; in Minneapolis-St. Paul it was 3° below Cincinnati. Required refrigeration capacity for the summer was the same for Cincinnati and Minneapolis-St. Paul and less than 2 percent greater for New Orleans. Winter requirements (table 4) were quite different with temperatures at New Orleans averaging as much as 20° above Cincinnati, and those at Minneapolis-St. Paul averaging 20° below Cincinnati. The required hourly steam capacity for each location reflects the effect of these large temperature differences.

TABLE 4.—*Dry and wet bulb temperatures in 3 cities, used as basis to determine refrigeration and heating capacity required for wholesale fruit and vegetable warehouses*

City	Summer			Winter	
	Dry bulb temperature	Wet bulb temperature	Refrigeration capacity required [1]	Dry bulb temperature	Steam capacity required
	° *F.*	° *F.*	*B.t.u./hr.*	° *F.*	*B.t.u./hr.*
Cincinnati, Ohio	95	78	684, 000	0	700, 000
New Orleans, La	95	80	696, 000	20	600, 000
Minneapolis-St. Paul, Minn	95	75	684, 000	−20	970, 000

[1] Capacity of ammonia system is 396,000 B.t.u. per hour. Dichlorodifluoromethane would be used for remaining capacity.

New Orleans, La.

The Cincinnati warehouse design was checked to determine to what extent it would have to be modified for the climate of the area represented by New Orleans. Since summer climates at both locations were similar, insulation requirements were the same. Only one change seemed desirable in the design: A portion of the outside wall in the boiler and mechanical equipment room was relocated to expose the condensers to the outside air (fig. 26). Mesh wire fencing at the outside edge of the partitioned area encloses the condensers. No other changes were necessary.

Minneapolis-St. Paul, Minn.

Extreme winter weather called for a number of changes to make the Cincinnati design suitable for the Minneapolis-St. Paul area. To protect both personnel and products from low temperature and snow, the rail and truck platforms and the truckloading dock were enclosed. Figure 27 illustrates the changes required. The truck enclosure extends out from the building a distance of 40 feet 8 inches. It is 34 feet wide with two doors to give the trucks access to the two loading positions. The depth of the lot had to be increased from 437 feet 8 inches (fig. 19) to 453 feet 4 inches to provide a minimum 75-foot-deep apron for trucks to back into the enclosure.

On the receiving platforms, columns supporting the canopy were moved out to the edge. A solid concrete block partition would be installed at the outer edge with seven doors on the truck receiving side and four doors on the rail side. An oil- or gas-fired hot-air heater would be installed at the outer corner where the truck and rail platforms join.

Ducts would extend out from the heater in two directions for complete circulation of hot air throughout the enclosed platform area. In addition to these changes, heavier steel members would be required for the roof structure to sustain added snow loads.

ESTIMATED CONSTRUCTION COSTS

Construction costs in a given area can be affected by the labor market, the amount of construction in the area, the kind of subsoil on the site, local building codes, building materials selected, structural design, and many other considerations. Cost estimates based on the design and materials specified in this report for a warehouse with a 1,000-carload annual capacity, to be located in the Cincinnati area, are given in table 5.

TABLE 5.—*Approximate construction costs for proposed service wholesale fruit and vegetable warehouse, Cincinnati, Ohio* [1]

Item	With refrigerated general storage area		Without refrigerated general storage area [2]	
Site work:	*Dollars*		*Dollars*	
Site preparation	3,000			
Excavation	3,934			
Sewers	2,824			
Concrete work	7,464			
Miscellaneous metals	332			
Fencing	6,930			
Paving	18,912			
Railroad spur	5,692			
Cleanup	3,000			
Total site work		52,088		52,088
Building:				
Excavation	14,666			
Concrete	45,454			
Masonry	20,466			
Steel	58,705			
Carpentry	10,326			
Roofing and roof insulation	34,334			
Metal siding, doors, windows, and specialties	5,992		7,456	
Interior finishing	14,272			
Monorail	638			
Automatic dockboard	1,595			
Total building		206,448		207,912
Mechanical and electrical:				
Insulation and finish	33,957		26,437	
Refrigerator doors	18,210			
Refrigeration systems	159,983		83,949	
Plumbing	27,190			
Air conditioning, office	9,865			
Heating, ventilating	29,948		50,083	
Electrical	21,548		21,308	
Incinerator	6,549			
Total mechanical and electrical		307,250		243,591
Subtotal		565,786		503,591
Overhead at 15 percent		84,868		75,539
Subtotal		650,645		579,130
Profit at 10 percent		65,065		57,913
Grand total		715,719		637,043

[1] Cost estimates were prepared by the McPherson Co. of Greenville, S.C. They were based on unit costs available for the Cincinnati area during the 3d quarter of 1957.

[2] Estimated costs were the same with or without a refrigerated general storage area except where figures have been entered in this column.

Total estimated cost of construction, including site work (but not the purchase cost of the site), building construction, mechanical and electrical work, and contractor's overhead and profit, is $715,719 for the warehouse with a refrigerated general storage area in addition to two cold storage rooms. When the general storage area is not refrigerated, the total estimated cost would be $637,043. Unit costs on which these estimates were based are dated as of the third quarter of 1957.

Estimated costs for a warehouse constructed in New Orleans are $598,116 with a refrigerated general storage area and $522,224 without it. Similar estimated costs for a Minneapolis location are $769,929 and $695,374. In each case, contractor's overhead was estimated at 15 percent of the cost of site, building, and mechanical and electrical work. The contractor's profit was estimated at 10 percent of the total of the construction and overhead costs.

EFFICIENT HANDLING METHODS

A modern warehouse designed to accommodate the latest materials-handing equipment does not in itself guarantee efficient handling operations. The facility and the equipment are necessary, but an alert management using good procedures makes the difference between low or high costs of operation. A well-designed warehouse with carefully selected handling equipment gives the service wholesaler the tools with which to do an efficient job.

Low-cost handling implies getting the job done with the fewest man-hours and, equally important, the fewest machine-hours. A high rate of utilization is necessary to justify the purchase of expensive handling equipment. Daily planning of equipment utilization and work assignments, as well as the use of unit loads, will help to minimize costs.

When the methods, crew arrangements, and equipment suggested in the following sections are used in a warehouse similar to those described in this report, the cost of the necessary handling operations will be kept to a minimum.

RECEIVING

The success of pallet handling operations can be attributed to two things: first, the use of the unit-load principle, and second, the use of vertical storage space. The unit-load principle is the grouping of a number of packages together so they may be handled as a single unit for receiving, transporting, storing, and truckloading. A fully loaded pallet would be a unit load. The wood pallet has a flat platform that distributes its imposed load uniformly across its surface. Two pallets can be tiered easily because of this feature, and vertical storage space can be fully utilized, provided the commodities are in containers that will sustain the added load. Pallet loads of commodities in sacks or other weak containers cannot be stacked two high without pallet racks or some similar support.

Studies show that in receiving operations where pallets are used the most effective crews consist of two or three men. In the two-man crew, one man is assigned to build pallet loads in a car or truck. He places a pallet as close to the work

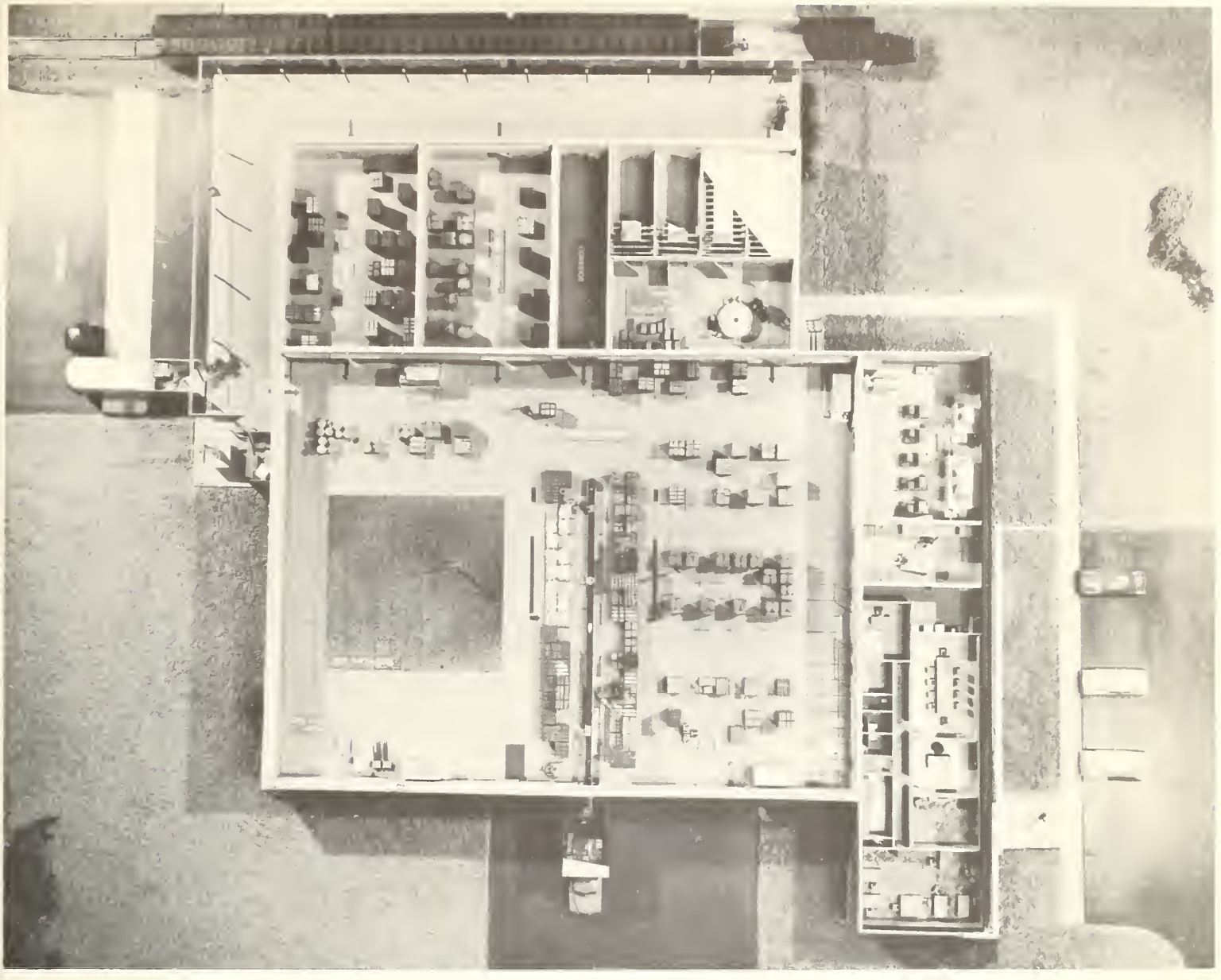

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FIGURE 25.—*Warehouse model, top view.*

face as possible to reduce the distance he must walk. Using a pallet pattern like those described in the appendix he places a predetermined number of packages in each load. With the aid of a pallet dolly or a pallet transporter he moves the pallet load from the carrier and places it on the dock. He then returns to the carrier and continues to unload. The second man operates a forklift truck. He picks up the loaded pallet from the platform, transports it to and places it in storage. Since a unit-load system and a fork truck are used, no additional labor for stacking is required in the storage area.

Three men require more hours for unloading than two men. However, a three-man crew can reduce the elapsed time for unloading, at an increased labor cost, if two men load the pallets. Two men may be required when 100-pound packages are being handled or when the condition of the carrier floor makes it difficult to move loaded pallets out of the carrier and onto the platform. The principal disadvantage of the three-man crew over the two-man crew is the greater number of man-hours required since two pallet loaders cannot do twice as much work as one.

CONSOLIDATING DEPLETED STOCKS

A forklift truck operator can pick up a loaded pallet on the platform, transport it 100 feet, place it in storage, and return to the carrier in less time than it takes one or even two men to load a pallet. If the man assigned to loading uses dollies or a transporter to move the loaded pallets out to the dock for pickup, the forklift truck operator can be assigned more than one job. For example, he could consolidate stock in the warehouse to make room for new supplies. The consolidation has to follow some plan of inventory control so that the first commodities into storage are always the first out, because the products handled in a service wholesale warehouse are perishable. If the consolidation of stock or other work is assigned to the forklift truck operator in addition to transporting produce from receiving platforms to storage areas, more complete use would be made of the forklift truck and the operator's time.

TRUCKLOADING

A service wholesaler accepts orders by telephone or through salesmen and makes deliveries directly to retail

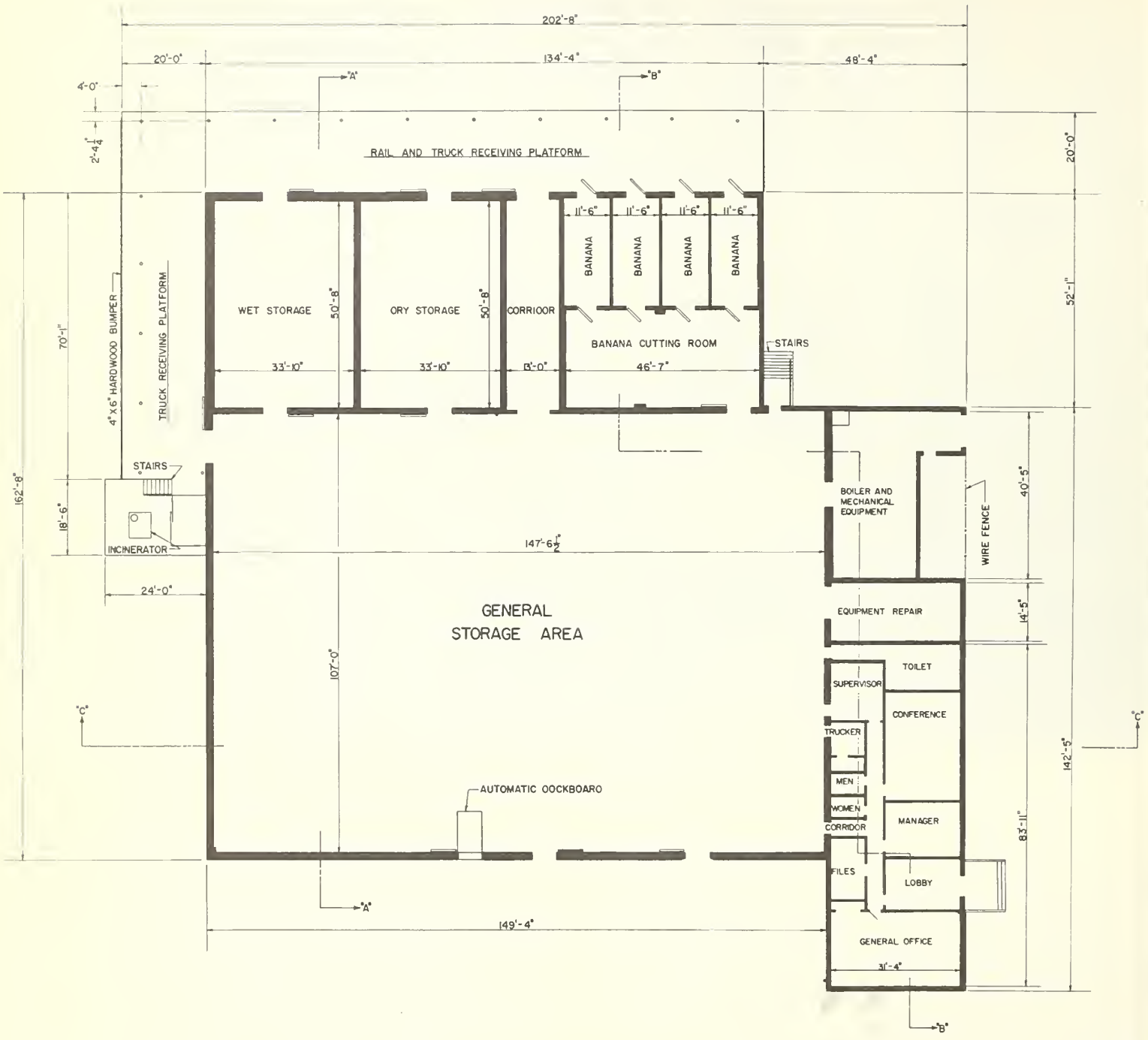

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FIGURE 26.—*Floor plan, New Orleans, La.*

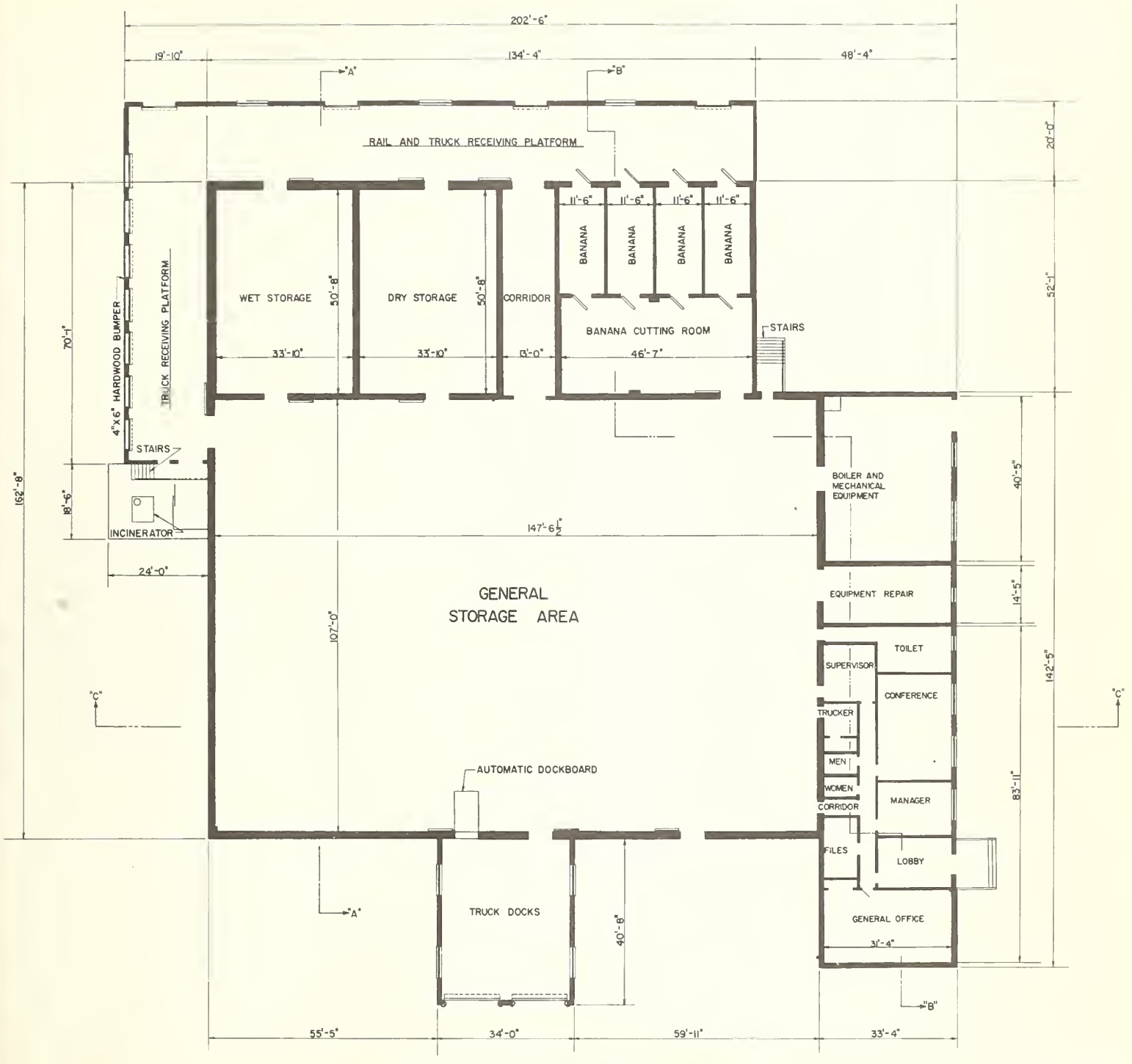

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FIGURE 27.—*Floor plan, Minneapolis-St. Paul, Minn.*

stores. The job of assembling orders and loading them on delivery trucks requires proper organization if the cost is to be minimized. A previous study of these operations (*4*) showed two equally efficient systems of organization for assembly and truckloading. One of these systems was incorporated in the warehouse layout shown in figure 10. A revised layout for the other system was also considered. (See fig. 16.)

The assembly and truckloading system for the warehouse layout shown in figure 10 utilizes unit loads of commodities, a long belt conveyor, a forklift truck, and a crew of seven men. A forklift truck operator assembles the required pallet loads. He drives the forklift truck to a storage point, picks up a pallet load, takes it to the order assembly area, and sets it down alongside the belt conveyor. He also resupplies the order assembly area while the trucks are being loaded, and removes the empty pallets. When all the trucks are loaded, he picks up pallet loads of produce left over and returns them to their assigned storage areas.

To maintain high productivity in truckloading, to which six men are assigned, the placement of pallets in the order assembly area follows a definite plan. Three men are belt loaders, two are truckloaders, and one man is the checker. All the commodities that move in large quantities are placed on one side of the line. Two belt loaders are assigned to that side. The balance of the items to be shipped are placed on the other side of the conveyor and one man assigned there. The sequence of commodities along the conveyor corresponds with the sequence in which the items appear on the preprinted invoice. This arrangement divides the workload and minimizes walking to commodity locations along the belt.

A truckloading crew of this size requires experienced men. The checker is the keyman since he assigns the work to the belt loaders, with the truckloaders in turn dependent on them. Any delay or inefficiency on the part of the checker reduces the productivity of the crew.

BANANA HANDLING

When four-wheel handtrucks with superstructures for eight stems are used for handling bananas, the most efficient crew consists of three men. One of the three men loads stems on a handtruck, the second man takes the loaded truck to the ripening room, and the third man hangs the stems in the ripening room. At least three handtrucks are required for maximum productivity with a crew of this size.

For cutting and packing bananas a five-man crew is most efficient (*2*). Three 4-wheel hand trucks, three self-taring scales, and one rotary table are used. One man brings out ripened fruit from the room and helps cut, one man cuts full time, and three men weigh and pack bananas, supply empty boxes to the packing line, and move full boxes away. The full boxes of bananas are placed on pallets and moved to the order assembly area or to a ripening room for holding until needed.

WAREHOUSE INNOVATIONS

Wholesalers have become interested in pallet tiering devices because they have been installed in the fruit and vegetable warehouses of some chainstores and group cooperatives. Pallet tiering devices have two advantages: (1) Vertical storage space can be more effectively used, and (2) physical damage to the packaged commodity can be avoided because each pallet is independently supported. The pallet load is transmitted directly to the floor and never rests on any packaged commodity. Pallets can be tiered three high, thus reducing the amount of horizontal floor space required.

Extending vertical storage space with pallet-supporting racks may cost less than building additional horizontal floor-space. Before deciding which to do, wholesalers need to know the cost of buying and installing the racks. They also need to calculate the dollar value of space lost because of clearances between horizontal and vertical rack supports and because of additional aisle space required. They should measure the cost of any additional labor that the stacking devices may require.

Researchers are currently making an engineering-economic evaluation of conventional pallet handling systems in comparison with those in which pallet tiering devices are used. When that work is completed, it will help wholesalers determine what cost reductions in warehouse construction they may achieve through the use of vertical storage systems.

Recently some wholesalers have constructed a single cold storage room in their new warehouses instead of the traditional separate wet and dry cold storages. Using one or two rooms present different problems in utilization of space, accessibility of the stored products, and capacity of refrigeration equipment, as well as the control of temperature and humidity. Improved methods are needed to maintain quality and prevent transfer of odors between products. Future research studies will be devoted to these problems in an effort to determine the economic and psysiological advantages or disadvantages of a single cold storage room compared to separate wet and dry cold storage rooms.

STEPS IN LAYOUT DEVELOPMENT

Some of the factors that a service wholesaler should consider in choosing a warehouse layout are (1) the kind of materials-handling equipment to be used, (2) the present and future annual volume of business, (3) the composition and seasonality of the business, (4) the rate of inventory turnover, and (5) the operations and services to be performed.

SELECTION OF MATERIALS-HANDLING EQUIPMENT

Seventy-five percent or more of the fruits and vegetables received at the warehouse of a service wholesaler are moved directly into storage, where they remain until ordered by customers. Then they are placed on trucks for delivery to retail stores. The physical operation is simply that of handling. Most commodities remain in their original containers from time of receipt to the time of shipment.

Efficient handling of commodities in the service wholesale business must be given primary consideration in planning a new warehouse. The wholesaler's decision as to the type of materials-handling equipment (*13*) and the methods to be used will largely determine the level of operating costs in a new warehouse. Handling equipment must be selected before the preparation of the warehouse layout. Many important warehouse features, such as door openings, ceiling clearances, and aisle widths, will be affected by the type of equipment to be used. Planning the warehouse to suit the equipment will permit efficient and economical handling. High operating costs and poor space utilization result when handling equipment is not selected until after the warehouse is built. In some instances this oversight has resulted in new warehouses that were no more efficient than modified old structures.

ANNUAL BUSINESS VOLUME

The accumulation of basic data is an important aspect of the determination of annual business volume. Past, present, and prospective volumes must be considered.

For many wholesalers the only information available is that of dollar volume handled rather than tonnages or carloads. While dollar volumes are better than nothing, they can be misleading. Fluctuations in prices of fruits and vegetables make dollar totals for one year hard to compare with totals of other years. The total can be affected by changes in tonnage handled or in prices or both. It can increase when tonnage decreases; this often occurs when bad weather reduces supplies of fruits and vegetables. When surplus quantities are available in the markets, tonnages moved may increase but dollar volumes decrease because of depressed prices.

Rather than relying entirely on dollar volumes, wholesalers should keep weekly, monthly, and annual records of the number of packages, pounds, or carload equivalents of each commodity handled. Required warehouse space is directly determined by the number of tons of each commodity to be stored there. Since different storage conditions are required to maintain the quality of different commodities, the space required for general storage, and for dry or wet cold storage areas should be based on the tonnage figures for the commodities stored in each area.

Tonnage records will indicate the volumes to be provided for in a new facility. If records are available for a number of years, they may indicate a growth trend. If the records show no pattern of growth, then the service wholesaler would have to use his best judgment in estimating the extent to which his business will expand.

The estimate of growth should be considered in two parts. First, the original warehouse structure should be large enough to handle any increase in volume expected in the next 5 to 10 years. Second, the design of the warehouse should permit easy expansion if the business continues to grow after that time.

FLUCTUATIONS IN BUSINESS VOLUME

Certain seasonal variations occur in the volumes of fruits and vegetables distributed at the wholesale level. In most sections of the country, wholesalers find that the tonnages moving through their warehouses drop appreciably when produce from the local growing area is available. In a typical warehouse, about 20 percent of the volume might be moved in a 4-month period, and about 80 percent in an 8-month period. The monthly rate of movement would be about 5 percent of the annual volume in the 4 slack months, and about 10 percent of the annual volume for each of the 8 active months. Each wholesaler should determine his own seasonal pattern. In some warehouses the peak volume will be concentrated in a few months. In others the monthly volume might be nearly uniform throughout the year.

It would not be practical to build enough space for peak volumes that occur for short periods. In some areas the Lenten season, Thanksgiving, and Christmas account for an acceleration in sales of fruits and vegetables. Volumes moved in these periods are substantially greater than normal. Space provided in the warehouse for these unusual volumes would not be used efficiently the rest of the year. It is preferable to use refrigerator cars as additional temporary space for storage to handle the short-term peaks.

In deciding how much space he will need, the wholesaler should use the average tonnage rate per month for that period each year in which he does most of his business. This rate should be one measure of the tonnage that will be handled in the new warehouse.

Variations in volume within a week should be checked also, to provide guidance for allocation of space for assembling and truckloading. In many warehouses the greatest volume of fruits and vegetables is moved out on Monday, Thursday, and Friday nights. The hourly capacity of conveyor lines, time limits for completing truckloading, and the system used for truckloading should be checked to determine how much space is needed for the high-volume nights.

INVENTORY TURNOVER

Business volumes and their monthly variations as well as the selection of a materials-handling system are all parts of the puzzle of allocating space in the new warehouse. Another important part is the rate of inventory turnover. This rate indicates the supply of fruits and vegetables that would be on hand at any one time. This quantity would be the actual basis for determining the number of square feet of storage space required.

The inventory turnover period varies a great deal for individual service wholesalers. It may range from 2 to 7 days or more. It is affected by the distance of each warehouse from the shipping points or terminal markets where the wholesaler makes his purchases, and by the quantities that he has to purchase.

Well-kept inventory records or records of tonnages sold daily can be used to find the rate of inventory turnover. Daily inventory postings provide the best basis for determining the average number of tons of produce in storage at any one time. This average total tonnage in storage divided by the average tonnage shipped daily would give the number of days' supply on hand. Both of these averages should be based on the normal business period omitting slow months.

When daily inventory records cannot be kept, total inventories taken on the 1st and 16th working days of each month give a reasonably good indication of average quantities in storage. If an inventory is taken each week it should not be taken on the day on which stocks are always depleted because of heavy shipments on the preceding day.

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APPENDIX

PALLET PATTERNS

A number of publications are available (*10*, *16*) that list and illustrate pallet patterns for 48- by 40-inch pallets. Patterns for a large number of container sizes are listed. Selecting a pattern for packages of fruits and vegetables is more complicated than it might be for other types of warehousing operations. Often more than one container size is used for each commodity. Container dimensions vary from one commodity to the other because of the different sizes and shapes of products. Pallet patterns may have to be revised for new containers that are frequently introduced.

Pallet patterns A to H shown in figures 28 to 44 are suggested for the containers illustrated and for the dimensions shown. Most of the patterns were observed in actual use in warehouses of service wholesalers. The container dimensions given in the illustrations are averages of actual measurements made in the warehouses. Containers that are larger or smaller than those illustrated will probably need different patterns. The best pattern would have interlocked packages with space for air circulation.

SPACE CALCULATIONS FOR COMMODITY STORAGE

It was assumed that 800 of the 1,000 carload equivalents would be handled in an 8-month period (35 weeks). The average weekly volume during this time would be 23 carload equivalents. Of these, it is assumed that 4 carloads per week would be bananas and 19 carloads would be the other fruits and vegetables normally handled.

The volume handled daily would be 3.2 carload equivalents, or one-sixth of the weekly volume of 19 carloads. Since a 4½-day supply would be on hand most of the time, storage space would be needed for 3.2 carloads per day times 4½ days, or a total of 14.4 carloads. To provide a minimum of extra space necessary for rewarehousing, inventory control, and stock rotation, this figure was increased to 15 carload equivalents for the calculations that follow. The 15 carloads were further subdivided so that 7 would be in general storage, 5 in dry cold storage, and 3 in wet cold storage. This breakdown was in the same ratio as the annual volumes of fruits and vegetables normally handled in each storage area. One hundred and fifty-six of 1,000 annual carload equivalents are bananas. This leaves 844 carloads of other fruits and vegetables. Of these, 423 move through general storage, 268 through dry cold storage, and 153 through wet cold storage (table 6).

TABLE 6.—*Annual volume of specified commodities stored in a wholesale fruit and vegetable warehouse, by storage areas*

Storage area and commodity	Quantity	Weight
General storage:	*Carloads*	*Tons*
Cantaloups	19	250. 8
Lemons	11	220. 0
Onions	27	405. 0
Potatoes	250	5, 000. 0
Sweetpotatoes	15	207. 0
Tomatoes	26	280. 8
Watermelons	29	382. 8
Other [1]	46	508. 0
Total	423	7, 254. 4
Dry cold storage:		
Apples	42	840. 0
Grapefruit	29	580. 8
Grapes	13	228. 8
Lettuce	110	1, 474. 0
Oranges	35	700. 0
Peaches	11	121. 0
Other [1]	28	498. 0
Total	268	4, 441. 8
Wet cold storage:		
Cabbage	45	562. 5
Carrots	26	455. 0
Celery	41	516. 6
Corn	15	187. 5
Other [1]	26	356. 0
Total	153	2, 077. 6
Total, all commodities	[2] 844	13, 773. 8

[1] See table 7 for weight calculations for individual commodities.
[2] 156 carload equivalents of bananas would bring the total to 1,000.

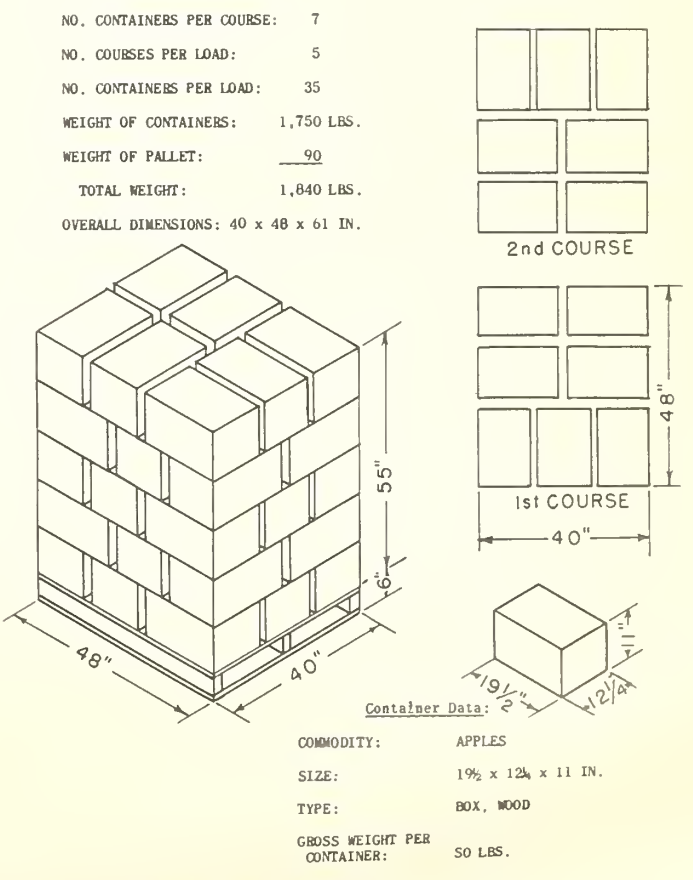


FIGURE 28.—*Pallet pattern A; apples.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 4

NO. COURSES PER LOAD: 5

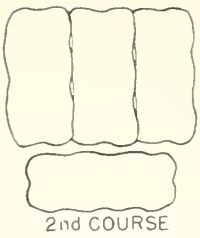
NO CONTAINERS PER LOAD: 20

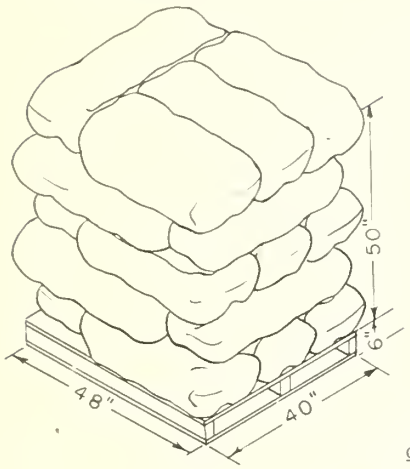
WEIGHT OF CONTAINERS: 1,000 LBS.

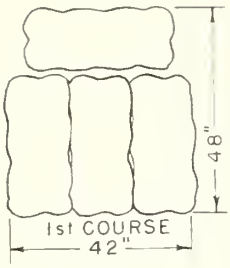
WEIGHT OF PALLET: 90

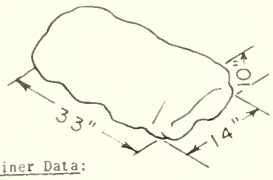
TOTAL WEIGHT: 1,090 LBS.

OVERALL DIMENSIONS: 42 x 48 x 56 IN.









Container Data:

COMMODITY: CABBAGE

SIZE: 33 x 14 x 10 IN.

TYPE: BAG, MESH

GROSS WEIGHT PER CONTAINER: 50 LBS.

FIGURE 29.—*Pallet pattern B; cabbage.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 7

NO. COURSES PER LOAD: 5

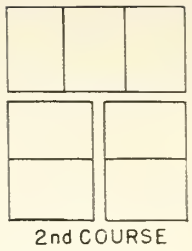
NO. CONTAINERS PER LOAD: 35

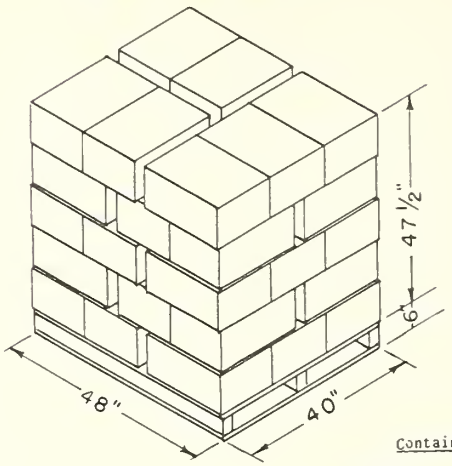
WEIGHT OF CONTAINERS: 1,750 LBS.

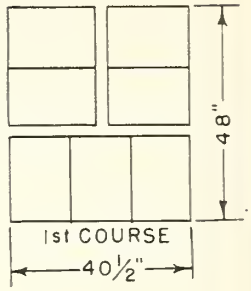
WEIGHT OF PALLET: 90

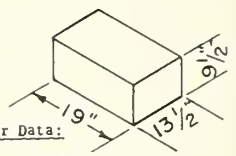
TOTAL WEIGHT: 1,840 LBS.

OVERALL DIMENSIONS: 40½ x 48 x 53½ IN.









Container Data:

COMMODITY: CARROTS

SIZE: 19 x 13½ x 9½ IN.

TYPE: BOX, FIBERBOARD

GROSS WEIGHT PER CONTAINER: 50 LBS.

FIGURE 31.—*Pallet pattern A; carrots.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 5

NO. COURSES PER LOAD: 4

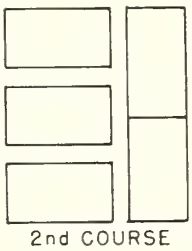
NO. CONTAINERS PER LOAD: 20

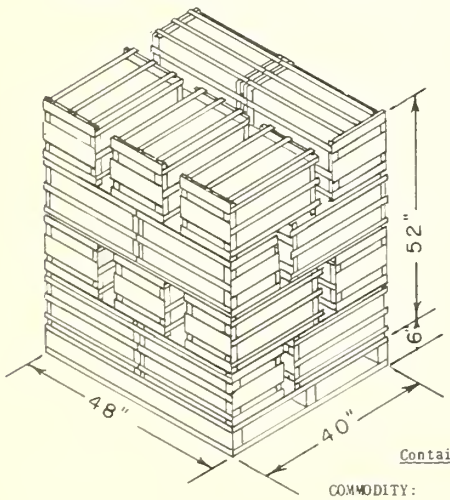
WEIGHT OF CONTAINERS: 1,700 LBS.

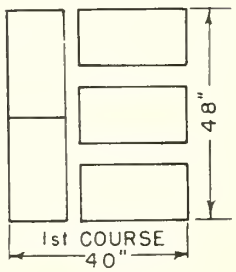
WEIGHT OF PALLET: 90

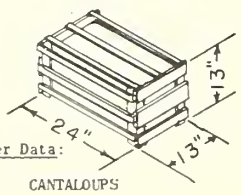
TOTAL WEIGHT: 1,790 LBS.

OVERALL DIMENSIONS: 40 x 48 x 58 IN.









Container Data:

COMMODITY: CANTALOUPS

SIZE: 24 x 13 x 13 IN.

TYPE: CRATE, WOOD

GROSS WEIGHT PER CONTAINER: 85 LBS.

FIGURE 30.—*Pallet pattern C; cantaloups.*

Unit Load Data:

NO. CONTAINERS PER COURSE: 6

NO. COURSES PER LOAD: 3

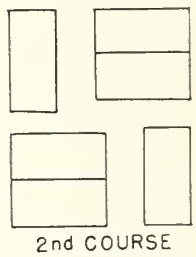
NO. CONTAINERS PER LOAD: 18

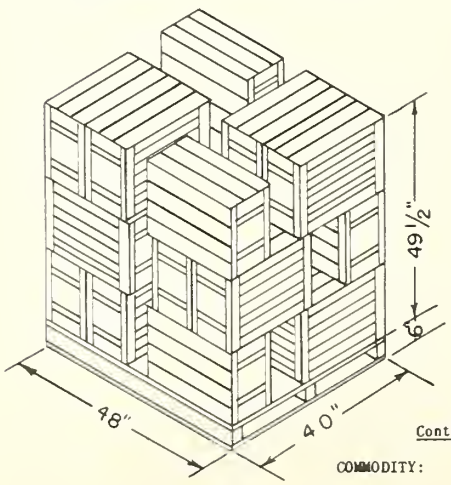
WEIGHT OF CONTAINERS: 1,080 LBS.

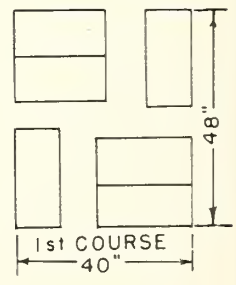
WEIGHT OF PALLET: 90

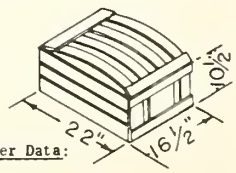
TOTAL WEIGHT: 1,170 LBS.

OVERALL DIMENSIONS: 40 x 48 x 55½ IN.









Container Data:

COMMODITY: CELERY

SIZE: 22 x 16½ x 10½ IN.

TYPE: CRATE, WOOD

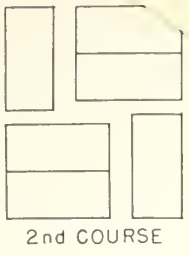
GROSS WEIGHT PER CONTAINER: 60 LBS.

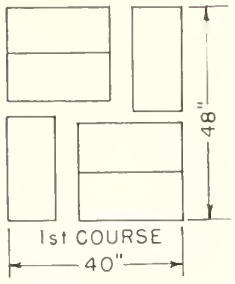
FIGURE 32.—*Pallet pattern D; celery.*

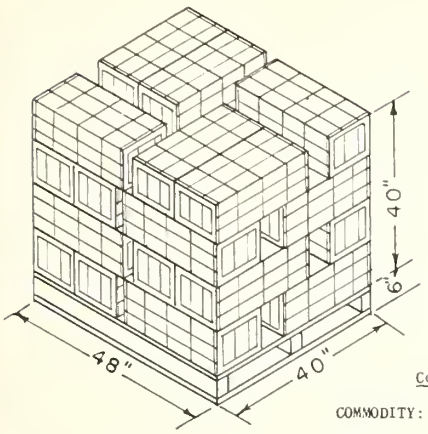
Pallet Load Data:

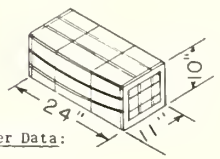
NO. CONTAINERS PER COURSE:	6
NO. COURSES PER LOAD:	4
NO. CONTAINERS PER LOAD:	24
WEIGHT OF CONTAINERS:	1,200 LBS.
WEIGHT OF PALLET:	90
TOTAL WEIGHT:	1,290 LBS.

OVERALL DIMENSIONS: 40 x 48 x 46 IN.









Container Data:

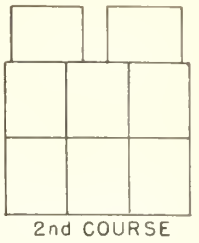
COMMODITY:	CORN
SIZE:	24 x 11 x 10 IN.
TYPE:	WIREBOUND CRATE, WOOD
GROSS WEIGHT PER CONTAINER:	50 LBS.

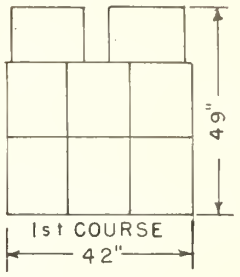
FIGURE 33.—*Pallet pattern D; corn.*

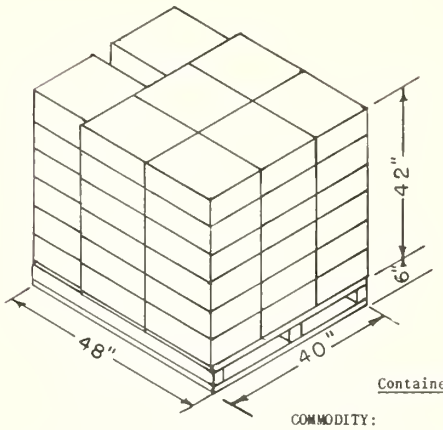
Pallet Load Data:

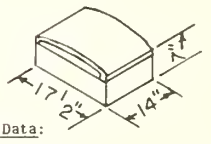
NO. CONTAINERS PER COURSE:	8
NO. COURSES PER LOAD:	6
NO. CONTAINERS PER LOAD:	48
WEIGHT OF CONTAINERS:	1,536 LBS.
WEIGHT OF PALLET:	90
TOTAL WEIGHT:	1,626 LBS.

OVERALL DIMENSIONS: 42 x 49 x 48 IN.









Container Data:

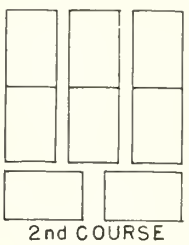
COMMODITY:	GRAPES
SIZE:	17½ x 14 x 7 IN.
TYPE:	LUG BOX, WOOD
GROSS WEIGHT PER CONTAINER:	32 LBS.

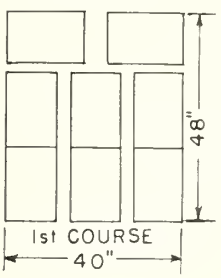
FIGURE 35.—*Pallet pattern E; grapes.*

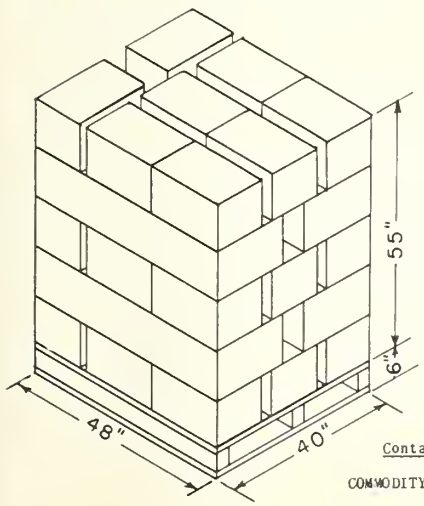
Pallet Load Data:

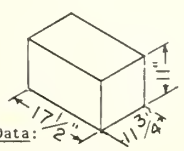
NO. CONTAINERS PER COURSE:	8
NO. COURSES PER LOAD:	5
NO. CONTAINERS PER LOAD:	40
WEIGHT OF CONTAINERS:	1,600 LBS.
WEIGHT OF PALLET:	90
TOTAL WEIGHT:	1,690 LBS.

OVERALL DIMENSIONS: 40 x 48 x 61 IN.









Container Data:

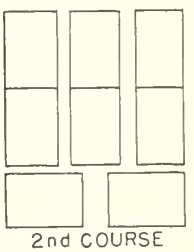
COMMODITY:	GRAPEFRUIT
SIZE:	17½ x 11-3/4 x 11 IN.
TYPE:	BOX, FIBERBOARD
GROSS WEIGHT PER CONTAINER:	40 POUNDS

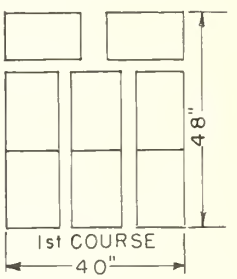
FIGURE 34.—*Pallet pattern E; grapefruit.*

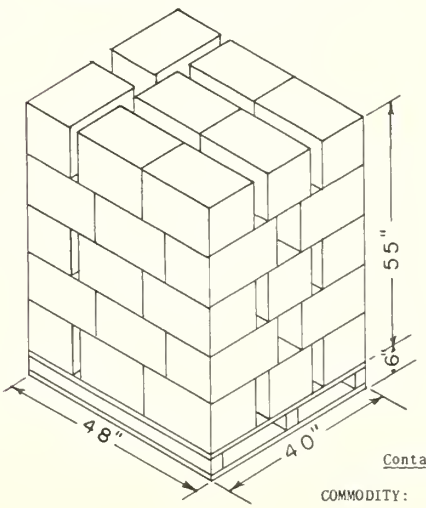
Pallet Load Data:

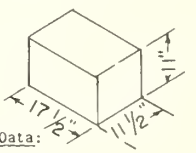
NO. CONTAINERS PER COURSE:	8
NO. COURSES PER LOAD:	5
NO. CONTAINERS PER LOAD:	40
WEIGHT OF CONTAINERS:	1,600 LBS.
WEIGHT OF PALLET:	90
TOTAL WEIGHT:	1,690 LBS.

OVERALL DIMENSIONS: 40 x 48 x 61 IN.









Container Data:

COMMODITY:	LEMONS
SIZE:	17½ x 11½ x 11 IN.
TYPE:	BOX, FIBERBOARD
GROSS WEIGHT PER CONTAINER:	40 LBS.

FIGURE 36.—*Pallet pattern E; lemons.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 6

NO. COURSES PER LOAD: 5

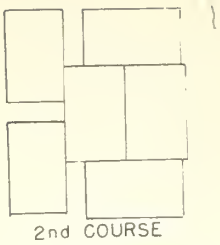
NO. CONTAINERS PER LOAD: 30

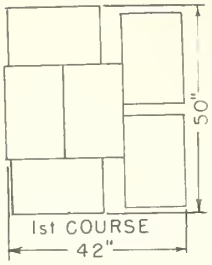
WEIGHT OF CONTAINERS: 1,260 LBS.

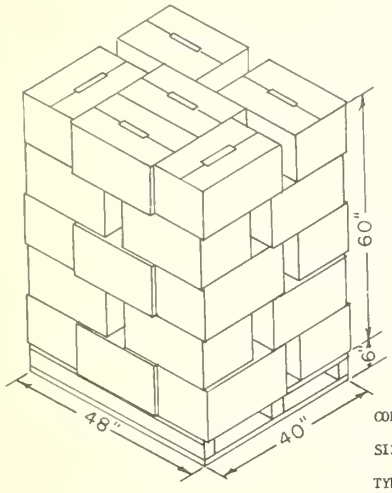
WEIGHT OF PALLET: 90

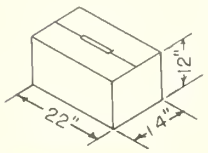
TOTAL WEIGHT: 1,350 LBS.

OVERALL DIMENSIONS: 42 x 50 x 66 IN.









Container Data:

COMMODITY: LETTUCE

SIZE: 22 x 14 x 12 IN.

TYPE: BOX, FIBERBOARD

GROSS WEIGHT PER CONTAINER: 42 LBS.

FIGURE 37.—*Pallet pattern F; lettuce.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 8

NO. COURSES PER LOAD: 5

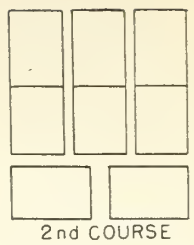
NO. CONTAINERS PER LOAD: 40

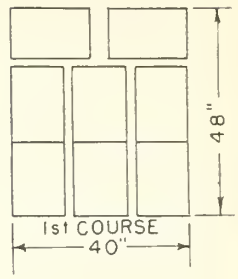
WEIGHT OF CONTAINERS: 1,600 LBS.

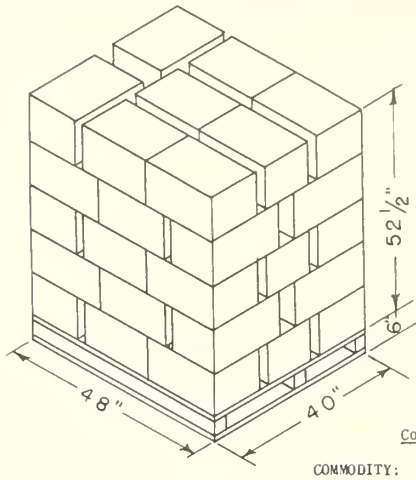
WEIGHT OF PALLET: 90

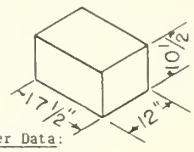
TOTAL WEIGHT: 1,690 LBS.

OVERALL DIMENSIONS: 40 x 48 x 53½ IN.









Container Data:

COMMODITY: ORANGES

SIZE: 17½ x 12 x 10½ IN.

TYPE: BOX, FIBERBOARD

GROSS WEIGHT PER CONTAINER: 40 LBS.

FIGURE 39.—*Pallet pattern E; oranges.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 6 (except for 4 on top)

NO. COURSES PER LOAD: 7

NO. CONTAINERS PER LOAD: 40

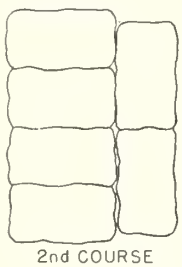
WEIGHT OF CONTAINERS: 2,000 LBS.

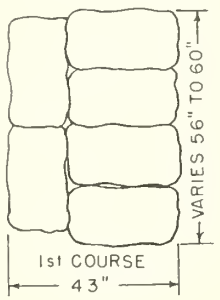
WEIGHT OF PALLET: 90

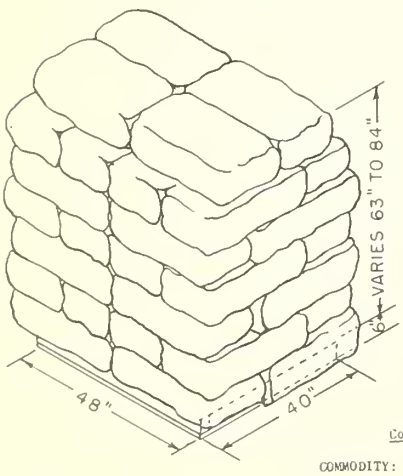
TOTAL WEIGHT: 2,090 LBS.

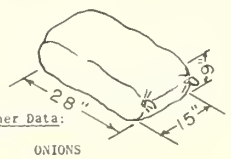
OVERALL DIMENSIONS: 43 x 60 x 84 1/ IN.

1/ Maximum









Container Data:

COMMODITY: ONIONS

SIZE: 29 x 15 x 9 IN.

TYPE: SACK, MESH

GROSS WEIGHT PER CONTAINER: 50 LBS.

FIGURE 38.—*Pallet pattern G; onions.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 6 (except for 2 on top)

NO. COURSES PER LOAD: 4

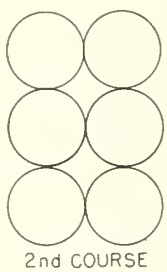
NO. CONTAINERS PER LOAD: 20

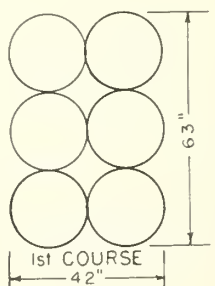
WEIGHT OF CONTAINERS: 1,100 LBS.

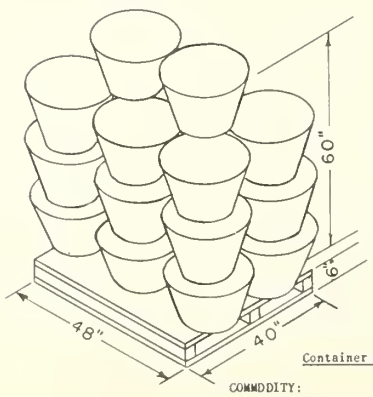
WEIGHT OF PALLET: 90

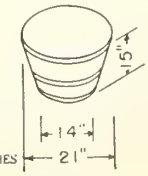
TOTAL WEIGHT: 1,190 LBS.

OVERALL DIMENSIONS: 42 x 63 x 66 IN.









Container Data:

COMMODITY: PEACHES

SIZE: 21 Diam. x 14 Diam. x 15 IN.

TYPE: BUSHEL BASKET, WOOD

GROSS WEIGHT PER CONTAINER: 55 LBS.

FIGURE 40.—*Pallet pattern H; peaches.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 6 (except for 4 on top)

NO. COURSES PER LOAD: 7

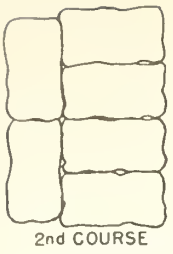
NO. CONTAINERS PER LOAD: 40

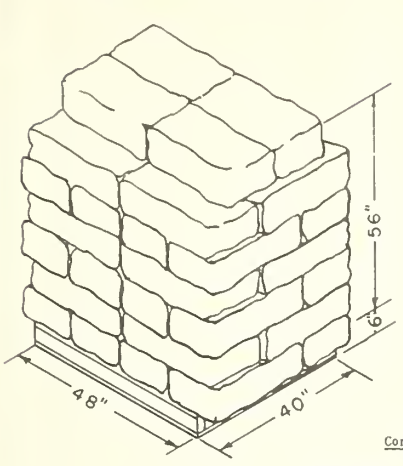
WEIGHT OF CONTAINERS: 2,000 LBS.

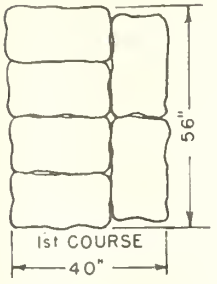
WEIGHT OF PALLET: 90

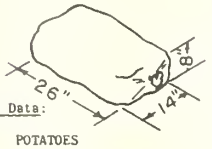
TOTAL WEIGHT: 2,090 LBS.

OVERALL DIMENSIONS: 40 x 56 x 62 IN.









Container Data:

COMMODITY: POTATOES

SIZE: 26 x 14 x 8 IN.

TYPE: SACK, PAPER

GROSS WEIGHT PER CONTAINER: 50 LBS.

FIGURE 41.—*Pallet pattern G; potatoes in 50-pound sacks.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 6 (except for 2 on top)

NO. COURSES PER LOAD: 4

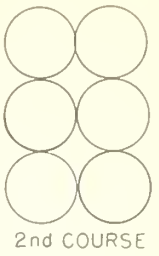
NO. CONTAINERS PER LOAD: 20

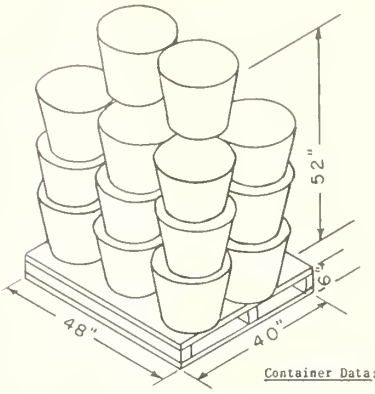
WEIGHT OF CONTAINERS: 1,100 LBS.

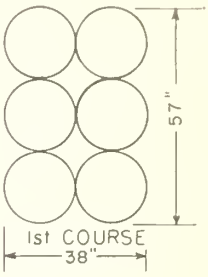
WEIGHT OF PALLET: 90

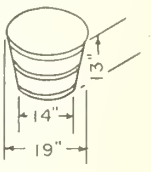
TOTAL WEIGHT: 1,190 LBS.

OVERALL DIMENSIONS: 40 x 57 x 58 IN.









Container Data:

COMMODITY: SWEET POTATOES

SIZE: 19 Diam. x 14 Diam. x 13 IN.

TYPE: BUSHEL BASKET, WOOD

GROSS WEIGHT PER CONTAINER: 55 LBS.

FIGURE 43.—*Pallet pattern H; sweetpotatoes.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 4

NO. COURSES PER LOAD: 5

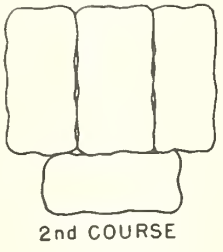
NO. CONTAINERS PER LOAD: 20

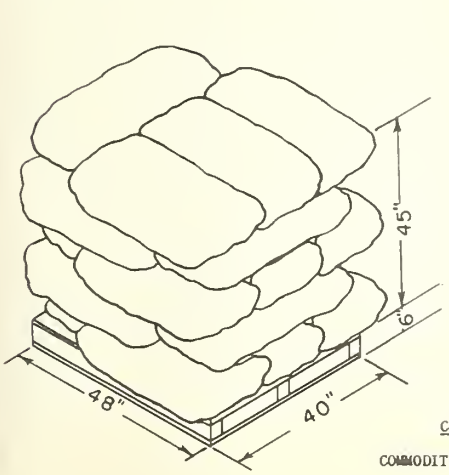
WEIGHT OF CONTAINERS: 2,000 LBS.

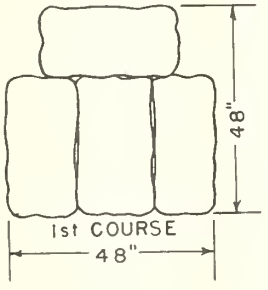
WEIGHT OF PALLET: 90

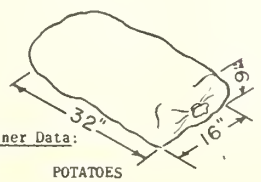
TOTAL WEIGHT: 2,090 LBS.

OVERALL DIMENSIONS: 48 x 48 x 51 IN.









Container Data:

COMMODITY: POTATOES

SIZE: 32 x 16 x 9 IN.

TYPE: SACK, BURLAP

GROSS WEIGHT PER CONTAINER: 100 LBS.

FIGURE 42.—*Pallet pattern B; potatoes in 100-pound sacks.*

Pallet Load Data:

NO. CONTAINERS PER COURSE: 8

NO. COURSES PER LOAD: 6

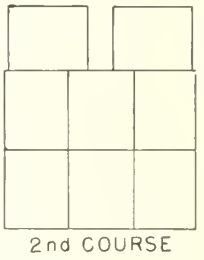
NO. CONTAINERS PER LOAD: 48

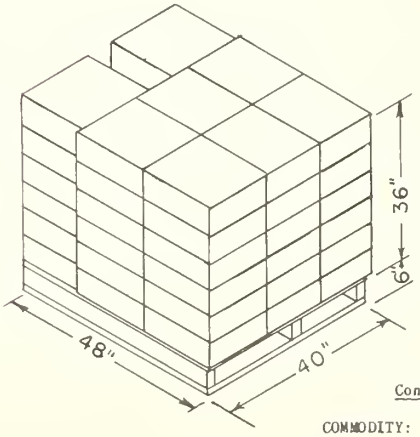
WEIGHT OF CONTAINERS: 1,536 LBS.

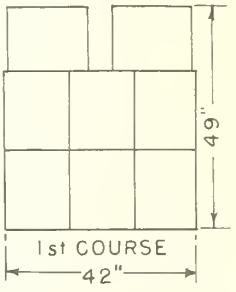
WEIGHT OF PALLET: 90

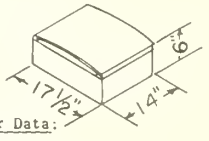
TOTAL WEIGHT: 1,626 LBS.

OVERALL DIMENSIONS: 42 x 49 x 42 IN.









Container Data:

COMMODITY: TOMATOES

SIZE: 17½ x 14 x 6 IN.

TYPE: LUG BOX, WOOD

GROSS WEIGHT PER CONTAINER: 32 LBS.

FIGURE 44.—*Pallet pattern E; tomatoes.*

Table 7 gives detailed information used to calculate weight and space requirements for those commodities that account for approximately 10 percent of the total annual volume handled by a typical wholesaler. The commodities are grouped according to the storage areas where they will be placed.

At this point it was necessary to assume that space requirements for an individual commodity depend upon its proportion to the 1,000-carload total. (See table 1.) It would have been more desirable to know actual inventory variations for each commodity. However, the records necessary for such a determination were not available. It is reasonable to assume that when one commodity is out of season others will be in season. The space not utilized by one would be used by the others.

The 15 carloads to be stored in the 3 storage areas were further subdivided into proportionate quantities of each commodity. Tables 8, 9, and 10 show this additional breakdown together with the number of pallet loads in each storage area and the floor space required.

Storage space requirements depend upon the average tonnage moved per month (based on past experience) during the normal business period. This tonnage divided by 26 days gives the average tonnage shipped out per working day.[4] This figure multiplied by the average number of days for which supplies are on hand at any one time gives the total tonnage to be provided for in the warehouse. It is desirable to increase this figure by 10 percent to allow enough space for consolidating depleted stocks and for rewarehousing operations.

[4] At a rate of 6 working days per week for 52 weeks divided by 12 months, each month has 26 working days.

OPERATIONS AND SERVICES

Most of the space in a produce warehouse is required for the storage of fruits and vegetables that remain in their original packages from the time of receipt to the time of shipment. These packages account for 75 percent or more of the tonnage handled.

In addition to space for storing packaged commodities, the service wholesaler usually needs additional space to perform certain services and operations. All service wholesalers have customers who purchase one or more items in less than full packages. To open packages and make up smaller weight units, the wholesaler will require from 200 to 300 square feet of floorspace for a workbench, a scale, and associated storage area.

A few service wholesalers ripen green tomatoes. This operation requires one or more ripening rooms as well as equipment for sorting and packing the tomatoes. Here again the volume handled will dictate the number of ripening rooms and the floor space required.

Prepackaging of fruits and vegetables in consumer units is becoming a more important operation each year. Since both the volume and the types of commodities packaged will affect the capacity and types of equipment needed, the wholesaler will have to determine the size and nature of this operation in advance of layout planning. A number of service wholesalers said that a minimum of 2,000 square feet should be provided in a warehouse designed for an annual volume of 1,000 carload equivalents. This space would accommodate sorting and packaging equipment for tomatoes as well as equipment needed for prepackaging other commodities.

TABLE 7.—*Annual quantity and weight data for "other" commodities stored in a fruit and vegetable wholesale warehouse, by storage area*

Storage area and commodity	Weight per package	Units per carload	Weight per carload	Estimated annual quantity	Annual weight	Annual units
General storage:	*Pounds*	*Packages*	*Tons*	*Carloads*	*Tons*	*Packages*
Green beans	33	620	10. 2	15. 7	160	9, 734
Cucumbers	56	450	12. 6	12. 8	161	5, 760
Eggplant	32	620	9. 9	2. 0	20	1, 240
Melons	50	310	7. 8	4. 7	37	1, 457
Okra	33	620	10. 2	1. 3	13	806
Sweet pepper	35	700	12. 3	9. 5	117	6, 650
Total or average	40	558	11. 0	46. 0	508	25, 647
Dry cold storage:						
Cranberries	27	1, 000	13. 5	1. 1	15	1, 100
Pears	50	750	18. 8	15. 6	293	11, 700
Summer squash	50	650	16. 2	11. 7	190	7, 605
Total or average	49	718	17. 5	28. 4	498	20, 405
Wet cold storage:						
Artichokes	24	1, 000	12. 0	0. 8	10	800
Asparagus	40	650	13. 0	3. 0	39	1, 950
Beans, lima	33	620	10. 2	1. 2	12	744
Beets	58	400	11. 6	1. 7	20	680
Broccoli	62	550	17. 0	1. 3	22	715
Brussel sprouts	25	630	7. 9	. 2	2	126
Cauliflower	60	400	12. 0	4. 7	56	1, 880
Peas, green	33	700	11. 6	1. 6	19	1, 120
Radishes	33	1, 200	19. 8	2. 8	55	3, 360
Spinach	52	700	18. 2	2. 4	44	1, 680
Turnips	70	400	14. 0	4. 6	64	1, 840
Endive	32	620	9. 9	. 4	4	248
Escarole	32	620	9. 9	. 9	9	558
Total or average	50	613	14. 5	25. 6	356	15, 701
Total or average, all commodities	46	618	13. 7	100. 0	1, 362	61, 753

TABLE 8.—*Floor area required to store 7 carloads of designated commodities in the general storage area of a wholesale fruit and vegetable warehouse*

Commodity	Weight per package	Annual carloads	Percentage of total carloads in general storage	Carload stored [1]	Packages to be stored	Average weight to be stored	Pallet pattern [2]	Number of pallets high	Commodity weight per pallet [3]	Pallets required	Pallet stacks required	Floor area required [4]
	Pounds	*Carloads*	*Percent*	*Carloads*	*Packages*	*Pounds*	*Pattern*	*Pallets*	*Pounds*	*Pallets*	*Stacks*	*Square feet*
Cantaloups	85	19	4. 5	0. 32	99	8, 415	C	2	1, 700	5	3	48. 6
Lemons	40	11	2. 6	. 18	180	7, 200	E	2	1, 600	5	3	48. 6
Onions	50	27	6. 4	. 45	270	13, 500	G	1	2, 000	7	7	113. 4
Potatoes	100	250	59. 1	4. 14	1, 656	165, 600	B	1	2, 000	83	83	1, 344. 6
Sweetpotatoes	55	15	3. 5	. 24	120	6, 600	H	1	1, 100	6	6	97. 2
Tomatoes	32	26	6. 1	. 43	290	9, 280	E	2	1, 536	6	3	48. 6
Watermelons	33	29	6. 9	. 48	384	12, 672	------	2	1, 200	11	6	97. 2
Other	40	46	10. 9	. 76	424	16, 960	------	1	1, 200	14	14	226. 8
Total	------	423	100. 0	7. 00	3, 423	240, 227	------	------	[5] 1, 753	137	125	2, 025. 0

[1] 7 carloads times the percentage of total carloads in general storage.
[2] See figs. 28 to 44 for pallet patterns.
[3] Gross weight of commodity only. Does not include pallet weight.
[4] Space required for pallet stacks only (52 by 43 inches plus 2-inch clearance). 16.2 square feet per pallet stack used.
[5] Average.

TABLE 9.—*Floor area required to store 5 carloads of designated commodities in the dry cold storage area of a wholesale fruit and vegetable warehouse*

Commodity	Weight per package	Annual carloads	Percentage of total carloads in dry cold storage	Carloads stored [1]	Packages stored	Weight stored	Pallet pattern [2]	Number of pallets high	Commodity weight per pallet [3]	Pallets required	Pallet stacks	Floor area required [4]
	Pounds	*Carloads*	*Percent*	*Carloads*	*Packages*	*Pounds*	*Type*	*Pallets*	*Pounds*	*Pallets*	*Stacks*	*Square feet*
Apples	50	42	15. 7	0. 78	624	31, 200	A	2	1, 750	18	9	145. 8
Grapefruit	40	29	10. 8	. 54	540	21, 600	E	2	1, 600	14	7	113. 4
Grapes	32	13	4. 8	. 24	264	8, 448	E	2	1, 536	6	3	48. 6
Lettuce	42	110	41. 0	2. 06	1, 318	55, 356	F	2	1, 260	44	22	356. 4
Oranges	40	35	13. 1	. 65	650	26, 000	E	2	1, 600	16	8	129. 6
Peaches	55	11	4. 2	. 21	84	4, 620	H	1	1, 100	4	4	64. 8
Other	49	28	10. 4	. 52	321	15, 729	------	1	1, 500	10	10	162. 0
Total	------	268	100. 0	5. 00	3, 801	162, 953	------	------	[5] 1, 455	112	63	1, 020. 6

[1] 5 carloads times the percentage of total carloads in dry cold storage.
[2] See figs. 28 to 44 for pallet patterns.
[3] Gross weight of commodity only. Does not include pallet weight.
[4] Space required for pallet stacks only (52 by 43 inches plus 2-inch clearance). 16.2 square feet per pallet stack used.
[5] Average.

TABLE 10.—*Floor area required to store 3 carloads of designated commodities in the wet cold storage area of a wholesale fruit and vegetable warehouse*

Commodity	Weight per package	Annual carloads	Percentage of total carloads in wet cold storage	Carloads stored [1]	Packages stored	Weight stored	Pallet pattern [2]	Number of pallets	Commodity weight per pallet [3]	Pallets required	Pallet stacks	Floor area required [4]
	Pounds	*Carloads*	*Percent*	*Carloads*	*Packages*	*Pounds*	*Pattern*	*Pallets*	*Pounds*	*Pallets*	*Stacks*	*Square feet*
Cabbage	50	45	29. 4	0. 88	440	22, 000	B	1	1, 000	22	22	356. 4
Carrots	50	26	17. 0	. 51	357	17, 850	A	2	1, 750	10	5	81. 0
Celery	60	41	26. 8	. 80	336	20, 160	D	2	1, 080	19	10	162. 0
Corn	50	15	9. 8	. 29	145	7, 250	D	2	1, 200	6	3	48. 6
Other	50	26	17. 0	. 52	321	16, 050	------	1	1, 000	16	16	259. 2
Total	------	153	100. 0	3. 00	1, 599	83, 310	------	------	[5] 1, 141	73	56	907. 2

[1] 3 carloads times the percentage of total carloads in wet cold storage.
[2] See figs. 28 to 44 for pallet patterns.
[3] Gross weight of commodity only. Does not include pallet weight.
[4] Space required for pallet stacks only (52 by 43 inches plus 2-inch clearance). 16.2 square feet per pallet stack used.
[5] Average.

Basic Space Unit

The 48- by 40-inch pallet was the basic unit used for determining areas required in the commodity storage places. The area of the pallet was increased by the amount of package overhang when required. Overhang of 3 inches on the 40-inch dimension and 4 inches on the 48-inch dimension was considered reasonable. With overhang the area is 52- by 43-inches. Package overhang could be as much as 1½ inches on each of the 40-inch sides and 2 inches on each of the 48-inch sides.

The number of packages of a commodity that can be stacked on a pallet is affected by the package dimensions. Tables 8, 9, and 10 indicate the gross weight by commodity that can be stored on each pallet. The pallet patterns for the commodities are shown in figures 28 to 44.

In selecting pallet patterns several criteria were considered. One of these was the maximum weight to be stored on pallets that are to be tiered. The limit assumed was 1,900 pounds. Pallets weigh approximately 90 pounds. The combined weight of commodity and pallet would be 1,990 pounds, which is within the load limit of a 2,000-pound-capacity forklift truck. Pallet loads that cannot be tiered can exceed that weight since they can be handled by electric pallet transporters that have a capacity of 4,000 pounds.

A second criterion was the height of the load built on the pallet. This applied particularly to pallets that can be tiered. A maximum load height of 60 inches was assumed. Maximum height of two tiered pallet loads is then 132 inches, including 6 inches for pallet height. The clear ceiling height specified for the warehouse was 144 inches. This gives a clearance of 12 inches for the pallet stack. This clearance is considered adequate for safety and for maneuvering required to place the second pallet load on top of the first.

Whenever possible, patterns were selected for all pallet loads to allow spacing of packages for effective air circulation. For commodities normally packaged in fiberboard containers, a pattern without overhang was chosen if possible. This was done to prevent placing the full load of the top pallet on the weak bottom sections of the containers. In a telescope container, for example, the greatest strength is in the sidewalls of the package, not in the top or bottom wall. When these packages overlap, the sharp edge or corner of the pallet cuts into the containers, frequently damaging the product. If the containers fail, the load may topple to the warehouse floor.

Pallet patterns that met these criteria resulted in the pallet loads indicated in tables 8, 9, and 10. When commodities can be tiered the floor space required is cut in half. For example, apples (table 9) require 18 pallets. However, since they can be tiered, space for only 9 pallet stacks is needed.

A minimum space of 2 inches between pallet stacks and loads allows pallets to be placed in storage easily and permits air to circulate. The floor space required for each pallet stack or load equals 15.5 square feet when overhang is included. With the addition of space for clearance, the basic area per pallet is 52 by 45 inches or 16.2 square feet. Using the latter figure, 2,025 square feet of general storage, 1,021 square feet of dry cold storage, and 907 square feet of wet cold storage space would be required. Space for aisles and other necessary features would increase these figures.

STORAGE CONDITIONS

A major consideration for everyone handling fresh produce is maintenance of quality. Biological scientists have determined that each commodity has its own special requirements of temperature and humidity (*17*, *1*). Close adherence to the conditions specified for each commodity from the shipping point to the consumer will help to keep the product fresh. Higher temperatures or lower humidities than those indicated in table 11 will accelerate the deterioration of the product.

Since the service wholesaler handles many different commodities he must arrive at some compromise on temperatures maintained. The desired temperature and humidity for each of the three storage areas are indicated in table 12.

TABLE 11.—*Recommended temperatures and humidities for selected fresh fruits and vegetables grouped by storage areas* [1]

Storage area and commodity	Temperature	Relative humidity
	° F.	*Percent*
General storage:		
Cantaloups	45 to 50	85 to 90.
Lemons	55 to 58	85 to 90.
Onions	32	70 to 75.
Potatoes	50	85 to 90.
Sweetpotatoes	55 to 60	85 to 90.
Tomatoes, ripe	50	85 to 90.
Watermelons	36 to 40	85 to 90.
Dry cold storage:		
Apples	30 to 32	85 to 90.
Grapefruit	[2] 32	85 to 90.
Grapes	31 to 32	85 to 90.
Lettuce	32	90 to 95.
Oranges, Florida	30 to 32	85 to 90.
Oranges, California	35 to 37	85 to 90.
Peaches	31 to 32	85 to 90.
Wet cold storage:		
Cabbage, early	32	90 to 95.
Carrots	32	90 to 95.
Celery	31 to 32	90 to 95.
Corn	31 to 32	85 to 90.

[1] Temperatures indicated are as low as practicable or safe. When higher temperatures are used storage life will be shortened. For greater detail see Wright, Rose, and Whiteman (*17*).

[2] For short-term storage only.

TABLE 12.—*Minimum temperature and humidity levels to be maintained in storage areas*

Storage area	Temperature	Relative humidity
	° F.	*Percent*
General storage	50	85
Dry cold storage	32	85
Wet cold storage	32	90

In most warehouses workmen must enter the storage areas often, making it difficult to hold temperatures and humidities constant. The temperatures and humidities shown in the table are guides for the selection of required insulation and refrigeration equipment. Temperature can be controlled more readily than humidity. Frequently vegetables are top iced in wet cold storage or sprinkled with water to keep humidity high.

Commodities should not be stacked so close together on pallets that air cannot circulate between packages. Without

adequate air circulation through the load, substantial temperature variations may occur in the room or within a stack of commodities.

If possible, blowers used to circulate the refrigerated air should be vaned or baffled so they do not blow air directly on the stored items. Air moving rapidly across an exposed product without a compensating increase in humidity results in dehydration of the outer surfaces of the product.

EVOLUTION OF HEAT BY PRODUCE

In addition to the cooling loads imposed by sun, wind, and outside temperatures, the engineer designing a warehouse refrigeration system must consider the heat given off by the stored commodities. Produce is alive and like other living things it breathes, releasing heat in the process. The amount of heat to be absorbed by the refrigeration system depends upon the temperature maintained in the storage area as well as the temperature of the product when it is moved into that area. When the temperature of a product such as cantaloups on receipt is 40° F., 1,960 British thermal units (B.t.u.) per ton are given off in 24 hours. When the temperature is 60° F., then the heat evolved per ton is 8,500 B.t.u.

The amount of data available on the evolution of heat from fruits and vegetables is limited. Table 13 indicates the heat evolved per ton in a period of 24 hours by a selected number of commodities stored at certain temperatures.

TABLE 13.—*Approximate rates of evolution of heat by certain fresh fruits and vegetables when stored at indicated temperatures* [1]

Storage area and commodity	Temperature	Heat evolved per ton per 24 hours
General storage:	° F.	*B.t.u.*
Cantaloups	40	1,960.
	60	8,500.
Lemons	50	1,610 to 3,670.
Onions	50	1,760 to 1,980.
Potatoes	40	1,100 to 1,760.
	70	2,200 to 3,520.
Sweetpotatoes	40	3,350.
	60	6,300.
Tomatoes, ripe	40	1,260.
	60	5,640.
Dry cold storage:		
Apples	32	700 to 800.
Grapefruit, Florida	32	370 to 950.
Grapes	32	602.
Lettuce	32	11,320.
Oranges, Florida	32	420 to 1,030.
Peaches	32	850 to 1,370.
Wet cold storage:		
Cabbage	32	1,200.
Carrots	32	2,130.
Celery	32	1,620.
Corn	32	6,560.

[1] For greater detail, see Wright, Rose, and Whiteman (*17*).

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